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EVALUATION OF SEDIMENT CHEMISTRY, TOXICITY, AND BENTHIC INVERTEBRATE COMMUNITY STRUCTURE IN SODA CREEK AND ALEXANDER RESERVOIR

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1. INTRODUCTION

This report documents work completed to date on investigations to characterize the quality of sediment and surface water in Soda Creek and Alexander Reservoir, near Soda Springs, Idaho. The work is part of the Remedial Investigation/Feasibility Study (RI/FS) of the Monsanto Company Elemental Phosphorus Plant in Soda Springs, Idaho.

As part of the remedial investigation (RI) sediments were collected from Soda Creek in 1992 (Phase I) and 1994 (Phase II). The Phase I investigations focused on determining if non-contact cooling water was a potential source of constituent input to Soda Creek (Golder 1992). Following additional sediment sampling as part of the Phase II RI, groundwater discharge of constituents of potential interest to Soda Creek has also been identified as a potential source of interest (Golder 1994a). Based on data collected to date, the U.S. Environmental Protection Agency (USEPA) concluded in the ecological risk assessment for the site (USEPA 1995) that cadmium and selenium in sediments posed a potential risk to sensitive aquatic organisms in Soda Creek.

Alexander Reservoir is an impoundment of the Bear River near Soda Springs, that supports a sport fishery and provides habitat to migratory birds. No measurements of water or sediment quality in Alexander Reservoir were made during either the Phase I or Phase II RI activities at the Monsanto site.

As a result of the potential risk to organisms in Soda Creek, the USEPA requested that Monsanto conduct additional sampling of sediment and macro-invertebrates in both Soda Creek and Alexander Reservoir. The purpose of the sampling was to determine the quality of the sediment and water in Soda Creek and Alexander Reservoir and whether the aquatic community in either Soda Creek or Alexander Reservoir had been affected by discharge of either the non-contact cooling water or the natural discharge of affected groundwater from springs south of the Monsanto plant.

Monsanto prepared a work plan to complete the sediment and water quality investigation (Golder, 1994b). The Work Plan was approved by the USEPA on November 2, 1994.

The objectives of the Work Plan were:

- to determine the concentrations and spatial distributions of constituents of potential interest (especially cadmium and selenium) in sediments of Soda Creek and in Alexander Reservoir at the mouth of Soda Creek;

- to sample suitable reference (background) sediments from Soda Creek and Alexander Reservoir for comparison purposes;

- to characterize the physical nature of the sediments;

- to characterize the biological toxicity of the sediments;

- to characterize the benthic invertebrate community structure at sample locations;

- to characterize the water quality overlying the sampled sediments; and
- to ensure sediment samples (test sediments and reference sediments) were collected from similar depositional environments to minimize variability.

To evaluate sediment quality in both Soda Creek and Alexander Reservoir, the Sediment Quality Triad (Triad) approach (Chapman 1992) was adopted. By using this approach, the information from: 1) chemical analyses on presence, concentration, and variability of constituents of potential interest; 2) ecological surveys on community structure of benthic invertebrates; and 3) toxicity testing are integrated to determine whether adverse ecological effects have occurred. If these effects are observed then the information can be used to establish a link between these adverse effects and the chemistry of the site. This memorandum describes all sediment and water quality data that has been collected from Soda Creek and Alexander Reservoir during all phases of the RI at the Monsanto plant.

2. ENVIRONMENTAL SETTING

2.1 Soda Creek

Soda Creek is a tributary to the Bear River in southeastern Idaho. Soda Creek forms the main surface water drainage feature of the valley north of Soda Springs. The valley is bordered by Soda Springs Hills and Ninety Percent Range on the west, the Blackfoot Reservoir on the north, the Aspen Range on the east, and the Bear River on the south (Figure 2-1). Soda Creek originates at Fivemile Meadows, an area of marshland and springs, flows south to Soda Creek Reservoir and eventually discharges into Alexander Reservoir west of the City of Soda Springs. Average annual flows for Soda Creek (at the Fivemile Meadows gauge for 1965 to 1986) is 18 cubic feet per second (cfs) (Hydrosphere 1993). Soda Creek passes within 2,000 feet of the Monsanto plant.

From Fivemile Meadows, Soda Creek flows into Soda Creek Reservoir, that has an approximate storage capacity of 2,500 acre-feet. Much of the water released from the reservoir re-enters Soda Creek through a spillway and a powerhouse located approximately 5,000 feet downstream of the reservoir. Further downstream of this powerhouse is the outfall used by Monsanto for discharge of non-contact cooling water (Section 3). Immediately downstream of the outfall (approximately 100 feet) is a diversion dam that redirects all of the Soda Creek flow year-round into a canal. Below this dam, Soda Creek is a meandering trickle with flows considerably less than one cfs. The flow rate in Soda Creek increases downstream due to groundwater discharge to the creek. Specific discharge points to Soda Creek downstream of the diversion dam are Southwest Springs, Mormon/Calf Springs, and Homestead Spring. Southwest Springs inflow is approximately 1,000 feet downstream of the diversion dam. Inflow to Soda Creek from Southwest Springs is less than 0.2 cfs. The inflow from Mormon/Calf Springs is approximately 1,500 feet downstream of the diversion dam. Inflow to Soda Creek from Mormon/Calf Springs is less than 0.2 cfs. Homestead Spring is approximately 4,500 feet downstream of the diversion dam and inflow is less than 0.02 cfs. Approximately 5,000 to 6,000 feet downstream of the diversion dam are two powerhouses, through which a portion of the Soda Creek flow is returned to the creek. The flow returned to the creek depends on power generation and demand for irrigation water. A second diversion dam on Soda Creek is located approximately 2,000 feet below the last powerhouse. This dam diverts water from Soda Creek into Soda Canal during the summer months. The remaining water in Soda Creek continues to flow southwest into Alexander Reservoir. The Soda Creek hydrology is illustrated schematically in Figure 2-2.

The Idaho Department of Health and Welfare (IDHW) has conducted evaluations of Soda Creek and tributaries in the vicinity of the Monsanto Plant. The state reports that Hooper Springs - a natural, sodic spring outside of the Plant boundaries has a natural but severe impact on the aquatic life in Soda Creek (Perry, J., IDHW- Division of Environment [Memo to G. Hopson, IDHW-Division of Environment] March 22, 1976). Hooper Spring discharges into Soda Creek to the west of the Monsanto Plant, well above the point of confluence with

Monsanto's National Pollution Discharge Elimination System (NPDES)-permitted, non-contact cooling water discharge into Soda Creek.

The IDHW study indicated that the diversity of Soda Creek benthic macroinvertebrate community is decreased due to the naturally-occurring highly mineralized and carbonated spring water that feeds the creek. The impact due to the high carbon dioxide content has been measured from the headwaters down to and below the outfall of the plant discharge. The water quality does improve in the lower reaches of the creek after the gas concentration has decreased, allowing the macroinvertebrate population to recover.

The IDHW study also included a fish survey. No fish were noted within the upper portions of Soda creek due to the harsh environmental conditions imposed by the naturally carbonated springs that feed the creek. Small numbers of fish (salmonids) were noted in the lower reaches of Soda Creek, about one mile above the confluence with the Bear River. The study concluded the Soda Creek ecosystem in proximity to the Plant consists of only "other aquatic life", and that no adverse environmental effects could be found to be attributable to the Monsanto discharge.

Soda Creek is not considered a sensitive habitat because it does not provide significant fish habitat. In addition, it is not critical habitat because no sensitive, threatened or endangered species use the creek as habitat.

2.2 Alexander Reservoir

Alexander Reservoir is an impoundment of the Bear River (Figure 2-1) downstream of the City of Soda Springs' wastewater treatment plant. The reservoir is used for recreation, irrigation, and hydroelectric power generation. During 1986 and 1988, average annual storage capacity was 12,410 and 12,607 acre-feet, respectively (Hydrosphere 1992). Minimum flows below the dam are 150 cfs. Normal elevation of the reservoir surface is 5,716 feet above sea level. During power generation, the reservoir elevation may fluctuate one to three feet.

Alexander Reservoir provides a marginal rainbow trout and yellow perch fishery. The reservoir also provides seasonal habitat for bald eagles, white pelicans, and Canada Geese.

3. PREVIOUS SURFACE WATER AND SEDIMENT INVESTIGATIONS

During Phase I and Phase II RI activities at the Monsanto Plant, samples were collected from the non-contact cooling water (Phase I) , surface water from Soda Creek and associated springs (Phase I), and sediments from Soda Creek (Phase I and II). The exposure pathways conceptual model for the Monsanto Plant (Golder 1991) identified the discharge of non-contact cooling water to Soda Creek as a potential exposure pathway for humans and ecological receptors. Therefore, samples were collected to evaluate the non-contact cooling water as a potential source and to determine the nature and extent of constituents of potential interest in the aquatic environment. The following briefly summarizes sampling and analysis conducted during the RI. Specific details are provided in Golder 1992 and 1994a.

The non-contact cooling water is used to cool the furnace shell and other equipment during phosphorus production. The water is obtained from production wells at the plant. The water passes over the outer furnace shell to maintain proper temperature and does not contact any process material. After leaving the furnace the water passes through a settling pond for cooling and particulate removal prior to being discharged, under a National Pollution Discharge Elimination System permit to Soda Creek. The non-contact cooling water is discharged into Soda Creek at an average annual rate of 4.5 cfs from an outfall immediately upstream of the diversion dam. Three samples were collected during the Phase I RI (Golder 1992) and results are shown in Table 3-1. Constituents detected in the non-contact cooling water are cadmium, calcium, fluoride, magnesium, nitrate-nitrogen, ortho-phosphate, selenium, sodium, and sulfate. Estimated constituent loading to Soda Creek from the discharge of non-contact cooling water is shown in Table 3-3.

A total of six surface water samples were collected from Soda Creek during the Phase I RI to determine if the constituents found in the effluent affected the water quality of Soda Creek (Golder 1992). Sample locations are shown in Figure 3-1. Three samples each were collected upstream and downstream of the Monsanto outfall. Because of the complete diversion of Soda Creek flow, the three samples downstream of the outfall were actually collected in the diversion canal. Analytical results for the surface water samples are shown in Table 3-1. A statistical comparison (t-test) between the reference (upstream) sample group and downstream sample group was made to determine which constituents attributable to Monsanto were present at elevated concentrations. The only chemical constituents found at statistically significant elevated concentrations downstream of the outfall in surface water were calcium, chloride, nitrate-nitrogen, sodium, and sulfate.

The water quality of Mormon Springs, which discharges into Soda Creek (Figure 3-1) has also been measured as part of the RI at Monsanto. Analytical results from water samples collected from Mormon Springs (Mormon A) since 1991 are summarized in Table 3-2. Results of the Phase II RI show that Mormon Springs is a discharge point for groundwater that migrates beneath the Monsanto Plant within the UBZ-2 groundwater zone (Golder 1994a). The RI identified a potential for future discharge of cadmium, fluoride, manganese, molybdenum, nickel, nitrate, and selenium from the UBZ-2 zone to Soda Creek. Estimated constituent loading to Soda Creek from Mormon Springs discharge is shown in Table 3-3.

Sediment samples from Soda Creek were collected during Phases I and II of the RI (Golder 1992 and 1994a). Samples were collected upstream (reference) and downstream of the non-contact cooling water outfall, and in several spring-fed creeks (Southwest, Mormon/Calf, and Homestead Springs), upstream from their confluence with Soda Creek. Sample locations are shown on Figure 3-2. In addition to testing for chemical constituents, selected sediment samples from Soda Springs were screened for biological toxicity during the Phase II RI. Chemical analyses for Soda Creek sediments collected during Phases I and II are summarized in Tables 3-4 and 3-5, respectively. The results of Phase II biological toxicity testing are shown in Table 3-6.

Based on data collected during the Phases I and II investigations, the Phase II RI concluded that arsenic, cadmium, nickel, selenium, silver, vanadium, and polonium-210 were present at elevated concentrations in sediments collected downstream of the Monsanto outfall. Although sediment samples collected downstream of the Monsanto outfall had higher toxicities than reference sediment samples, the reference samples had an inherent toxicity relative to laboratory controls. Consequently, the toxicity testing did not conclusively show that constituents released to Soda Creek, either through the outfall or through groundwater discharge, could cause an adverse ecological effect.

Using information from the Phase II RI, USEPA performed an ecological risk assessment that included Soda Creek sediments (USEPA 1995). The risk assessment evaluated potential exposure of aquatic receptors to constituents found in sediments. The risk assessment characterized the aquatic habitat of Soda Creek as naturally harsh due to high levels of carbon dioxide in the water. Consequently, the creek does not support a rich (i.e., diverse) ecosystem nor provide a trout fisheries resource, except near the confluence with Alexander Reservoir. The risk assessment evaluated impairment of aquatic habitat as an ecological endpoint by comparing sediment and water quality to proposed or promulgated criteria. For sediments, the risk assessment found that arsenic, cadmium, copper, nickel, and selenium all exceeded surrogate sediment quality reference levels. The risk assessment concluded, however, that because Soda Creek represented a limited habitat, there was little potential for adverse impact due to the presence of these constituents in sediment.

4. CURRENT INVESTIGATION

The current investigation was required by USEPA to provide additional information for the Phase II RI on the potential effect to the aquatic environment of Soda Creek or Alexander Reservoir posed by releases of substances from the Monsanto plant. The information collected as part of this investigation is intended to supplement data collected by previous RI activities. The information presented is intended to resolve outstanding issues regarding ecological risk in Soda Creek.

4.1 Sample Locations

Based on previous investigations of Soda Creek, the creek was divided into 10 reaches that were intended to reflect similar hydrology and sediment deposition characteristics. Reach boundaries were determined during a reconnaissance survey and reviewed on November 7 and 8, 1994 by USEPA just prior to sampling. Three reaches located upstream of the Monsanto non-contact cooling water outfall were chosen for collection of reference samples (SCC-1, SCC-2, and SCC-3). The remaining seven reaches (SC-1, SC-2, SC-3, SC-4, SC-5, SC-6, and SC-7) were located downstream of the outfall to the confluence of Soda Creek with Alexander Reservoir (Figure 4-1). The reaches downstream of the outfall were selected to identify the downstream distribution of the constituents of potential interest.

Within each reach, the sample station was determined by selecting the first depositional zone encountered beginning at the downstream boundary of the reach. At each station in Soda Creek, three replicate samples (e.g., SC-1A, SC-1B, and SC-1C) were collected. Sediments from Soda Creek were sampled between November 11 to 16, 1994. Each replicate sample was collected from a 3- × 6-ft area. In addition to the depositional sample station, the closest upstream erosional zone was also sampled for benthic invertebrate analysis.

Sediments at a total of 18 stations were sampled in Alexander Reservoir (Figure 4-1) between November 6 to 10, 1994. Nine stations were located at the mouth of Soda Creek: ARS-1, ARS-2, ARS-3, ARS-4, ARS-5, ARS-6, ARS-7, ARS-8, and ARS-9. These stations were located to allow evaluation of spatial distribution in constituents of potential interest as Soda Creek enters Alexander Reservoir. The remaining nine stations (ARC-1, ARC-2, ARC-3, ARC-4, ARC-5, ARC-6, ARC-7, ARC-8, and ARC-9) were sampled as reference stations and were located in Alexander Reservoir (Figure 4-1) so as to be unaffected by Soda Creek.

4.2 Sample Collection

Sample collection proceeded in a downstream to upstream direction. Surface sediment samples (0 to 2.5 in) were collected from Alexander Reservoir and from depositional zones in Soda Creek using a petite Ponar grab [0.25-ft^2 (0.023-m^2) area]. Samples were collected for benthic invertebrate analysis and for chemical, toxicity, and physical properties. Each analytical sample was a composite of two grabs of the surface layer. Samples for chemical, toxicity, and physical properties were collected before benthic samples to minimise the possibility of cross-contamination. Samples for chemical analysis were transferred into glass sample jars; samples for toxicity testing and physical properties were transferred to one-gallon plastic bags.

Benthic samples were passed through a 500 μm mesh sieve to remove silt. The remaining material was then transferred to a labelled, plastic, 1-L container and was preserved in 10% formalin.

A Surber sampler was used to collect benthic samples from erosional sites (Gibbons et al. 1993). The Surber sampler encompassed an area of 1-ft^2 (0.092-m^2) and the collecting net had a mesh size of 363 μm. At each sampling site, the sampler was placed on the bottom and the enclosed bottom material was manually disturbed for approximately one minute to remove all attached invertebrates. After removal of the sampler from the stream, the contents of the net were transferred into a labelled, plastic, 1-L container and were preserved in 10% formalin. All erosional samples were taken in areas with predominantly cobble/gravel substrata as close to mid-channel as possible. The collection net was back-washed to remove any clinging organisms and the sampler was rinsed before taking the next sample.

Sediment samples were also collected at depth from five locations in Soda Creek (SCC-1, SCC-3, SC-2, SC-4, and SC-5) and four locations in Alexander Reservoir (ARC-3, ARC-6, ARS-2, and ARS-9) using a 2-inch hand corer. The objective of collecting core samples was to allow depth profiling of chemical constituents. After collection, core samples were subdivided based on observed sedimentation units and transferred into glass jars for transport to the laboratory.

Surface water samples were also collected at selected sampling stations in Soda Creek (SCC-1, SCC-3, SC-2, SC-3, SC-4, and SC-6) and Alexander Reservoir (ARC-3, ARC-6, ARS-2, and ARS-9). Water samples were collected approximately one-foot above the sediment surface. Water samples from the creek were collected directly into a sample bottle. Water samples from the reservoir were collected using a 2-L VanDorn water sample bottle and then transferred to a sample bottle. After collection, aliquots were tested for pH, conductivity, temperature, and dissolved oxygen.

Sediment samples were analyzed for arsenic, cadmium, copper, molybdenum, nickel, selenium, silver, vanadium, total organic carbon, pH, and grain-size distribution. Surface water samples were analyzed for cadmium, calcium, selenium, sodium, alkalinity, hardness, and total dissolved solids.

4.3 Benthic Community Analysis

Samples of benthic invertebrates were sorted and identified according to standard methods developed using the appropriate scientific literature (Klemm et al. 1990, APHA et al. 1989, Gibbons et al. 1993). First, each sample was elutriated to remove sand and gravel and was passed through a 1-mm sieve, which separated it into coarse and fine size fractions. Subsampling was employed only for large samples, and only for the fine size fraction, according to methods outlined by Wrona et al. (1982). Invertebrates were removed from the organic detritus under a dissecting microscope and were identified to the lowest practical taxonomic level, typically genus for most insects. Small, early instar animals were identified to the lowest taxonomic level possible, generally to family. Identifications were made using recognised taxonomic keys (Edmunds et al. 1976, Wiggins 1977, Merritt and Cummins 1984, Brinkhurst 1986, Stewart and Stark 1988, Pennak 1989, Clifford 1991). Invertebrate numbers were tabulated by site.

As a quality control measure, invertebrates from three samples (one from Alexander Reservoir; two from Soda Creek) were re-identified by an additional taxonomist. Ninety percent agreement (calculated as the sum of minimum numbers of each taxon in a re-identified sample/mean total invertebrates in the same sample × 100) was deemed as the acceptable minimum degree of agreement between taxonomists.

4.4 Toxicity Testing

Whole sediment toxicity tests were conducted with *Chironomous tentans* (10-day exposure) based on standard test methods (ASTM 1993). There were two measures of toxicity: mortality (percent) and growth (dry weight/organism). Overlying dilution water was supplemented with sodium bicarbonate (C_{Na} = 33 mg/L) to approximate conductivity, alkalinity, and sodium content of site surface waters (Soda Creek and Alexander Reservoir).

Sediments were homogenized with interstitial water present in the sample container and dispensed into beakers. Sediments were not sieved prior to testing. Four hundred milliliters of adjusted dilution water was added to the sediments and the sediments allowed to settle overnight. Laboratory controls consisted of 100 mL of acid-washed silica sand (70 mesh) and 400 mL of the adjusted dilution water. Testing was conducted using three replicates of each sample and six replicates of each laboratory control. Test vessels were aerated for approximately one-hour prior to test initiation.

At test termination (Day 10), the sediments were sieved and the number of surviving chironomids recorded. The chironomids were then dried at 60°C and weighed to assess growth.

Significant differences in mortality and growth of organisms in test sediments relative to the laboratory controls were determined by the toxicity laboratory (HydroQual, Ltd.) using the t-test (TOXSTAT, Gulley et al. 1991).

4.5 Data Analysis and Statistics

The data for Soda Creek consists of three samples from each of the 10 stations (three reference and seven test stations). For Alexander Reservoir, the data consists of nine samples collected from a reference area and nine samples collected from the test area near the mouth of Soda Creek (Figure 3-1). Samples collected near the mouth of Soda Creek were divided on the basis of their distance from the mouth of Soda Creek into 3 groups, of 3 samples each. Group 1 (ARS-1, ARS-2, and ARS-3) is the farthest from Soda Creek, Group 3 (ARS-7, ARS-8, and ARS-9) is the closest to Soda Creek, and Group 2 (ARS-4, ARS-5, and ARS-6) is between the other two groups.

The chemical concentrations in the creek and reservoir sediment samples were standardized to sample clay content to minimize differences because of changes in sample grain-size. Clay content was used because these particles have a relatively large surface area to volume ratio and a surface electric charge. Together these properties increase the likelihood of constituent sorption and make the clay fraction more chemically and biologically reactive (Power and Chapman 1992).

Samples with results that were less than the detection limit were replaced with one-half the detection limit. Molybdenum concentrations in reservoir samples were all less than the detection limit and only Soda Creek stations SC-2 and SC-3 had all three samples above the detection limit. Consequently, molybdenum was not included in the statistical analyses for either the creek or the reservoir.

Before data analysis, the invertebrate data matrices were reduced to exclude rare taxa (Culp and Davies 1980, Pontasch et al. 1989, Corkum 1990, Whitehurst and Lindsey 1990). Abundant species contain most of the information in the sample, and since their densities are higher, relationships among sites may be detected more reliably (Gauch 1982). The invertebrate data matrices were reduced to include only those taxa that collectively constituted >95% of total invertebrates, as reflected by totals for each taxon across all sites. Data reduction was performed separately for Soda Creek and Alexander Reservoir. Data from samples collected in the erosional zone of Soda Creek were not included in the analysis because no chemical or toxicity data were collected.

The results of the statistical tests described below are considered to be significant when the probability of a false positive or Type I error (p) is 0.05.

4.5.1 Sediment Chemistry

Variances of constituent concentrations among the creek stations or among the reservoir groups were heterogeneous. Therefore, the data was transformed ($\log_{10}$) before statistical analysis. Comparisons of mean composition for all of the metals at each station (creek) or group (reservoir) were made using a one-way multivariate analysis of variance (MANOVA; Seber 1984). A balanced design was used for samples from the creek and an unbalanced design was used for samples from the reservoir. Given a statistically significant difference in the MANOVA, a one-way univariate analysis of variance (ANOVA; Milliken and Johnson 1984) was used to identify significant differences for individual chemical constituents. The MANOVA was performed prior to the univariate ANOVAs to maintain the false positive rate of 0.05. When one-way univariate ANOVAs are performed for each of the seven chemical constituents plus pH and evaluated independently at a false positive error rate of 0.05, the experiment - wise false positive error rate is 0.34. For significant differences in chemical constituents in creek samples, a Tukey-Kramer multiple comparison test (Neter et al. 1985) was performed to determine simultaneously which of the stations are significantly different from the reference stations. For significant differences in chemical constituents in reservoir samples, Dunnett's multiple comparison test (Steel and Torrie 1980) was performed to determine simultaneously which of the groups are significantly different from the reference area.

4.5.2 Benthic Community

A MANOVA with the same design layout as described in Section 4.5.1 was performed using the benthic organisms that contribute at least 5% of the total number of invertebrates for two or more stations, total invertebrates and number of taxa. The benthic organisms included in the MANOVA for the creek were Tubificidae, Tantytarsini, Orthocladiinae, *Chironomus* sp., and Tanypodinae. The MANOVA for the creek was performed on the $\log_{10}$ transformation of the data. The benthic organisms included in the MANOVA for the reservoir were Tubificidae, *Chironomus* sp., and Naididae.

The MANOVA indicates whether there is a statistically significant difference in the benthic fauna between two or more stations or groups. If there is no statistically significant difference in the benthic fauna, then there cannot be a significant association between the sediment chemistry and the benthic fauna. If there is a statistically significant difference in the benthic fauna, then it needs to be determined if there is a significant association between the sediment chemistry and the benthic fauna and if this association indicates an effect on the benthic fauna community.

Canonical Correlation Analysis (CCA) was used to assess the degree of relationship between the sediment chemistry and the benthic fauna (Harris 1975). CCA is an extension of multiple regression. For example, in a multiple regression, the abundance of Tubificidae would be predicted from a linear combination of the concentrations of the different chemical concentrations. A multiple regression would be performed separately for each benthic organism. In CCA, two linear combinations are formed, one for the sediment chemistry and one for the benthic fauna. The linear combinations are called canonical variates and the coefficients in the linear combinations are called the canonical coefficients. The correlation between the canonical covariate for sediment chemistry and the canonical covariate for benthic fauna is called the canonical correlation. The square of the canonical correlation is analogous to R-squared (coefficient of determination) in a multiple regression and is used to determine the statistical significance of the association between the sediment chemistry and benthic fauna. The CCA is performed instead of a series of multiple regressions to maintain the false positive error rate of 0.05 with a set of seven chemical constituents and seven benthic fauna attributes, the probability of one or more false positive results occurring in the 49 individual correlations, between these two sets is 0.92.

More than one set of canonical covariates are estimated. The first set of canonical covariates are estimated so that the canonical correlation is maximized. The second set of canonical covariates produce the second highest canonical correlation. The process continues until the number of sets of canonical covariates that are estimated is equal to the number of variables in the smaller set. Each canonical covariate is uncorrelated with all the other canonical covariates of either set except for the one corresponding canonical covariate in the same set.

The data for each variable used in the CCA was standardized to a mean of zero and a variance of one. This standardization allows the interpretation of the canonical coefficients, where the absolute magnitude of a canonical coefficient for a given variable relative to the other canonical coefficients of the other variables indicates the relative importance of that variable in the relationship between the sediment chemistry and the benthic fauna.

4.5.3 Toxicity Testing

Three replicate toxicity tests were performed for each of the sediment samples collected in the creek and the reservoir. Additionally, there were four laboratory control toxicity tests of six replicates each. Several of the toxicity tests were found to contain leaches. Because leaches are predatory on the test organisms, the results were deleted from the statistical analysis. Additionally, the toxicity tests were repeated for two samples, those results are included in the analysis.

Comparisons of percent mortality and growth between stations (creek) and groups (reservoir) were made using an unbalanced nested ANOVA (Milliken and Johnson 1984). Significant differences were tested using the Tukey-Kramer multiple comparison test so that all pairwise comparisons are evaluated. The rank transformation of the data were used in the statistical analyses for creek samples due to the heterogeneity of variance.

5. INVESTIGATION RESULTS

5.1 Sediment and Surface Water Characterization

The physical characteristics of collected sediments are summarized in Table 5-1. Sediment organic carbon ranged from 2.4% to 9.1% in Soda Creek and 1.7% to 9.0% for reservoir samples. Sediment samples from the creek and the reservoir were predominantly sandy-silt-sized particles with minimal differences between creek and reservoir samples. The pH ranged from 6.4 to 7.3 in creek sediments and from 7.0 to 7.6 in the reservoir sediments. The sediment pH was slightly higher in the reference samples collected in the reservoir relative to the pH in the test sediments.

Concentrations of total metals in whole-sediment samples from Soda Creek and Alexander Reservoir are summarized in Tables 5-2 and 5-3, respectively. Station SC-3 in Soda Creek had the highest concentrations of molybdenum, nickel, and selenium; station SC-5 had the highest concentrations of cadmium, copper, and vanadium; and station SC-6 had highest concentrations of arsenic and silver. Metal concentrations in sediment samples exceeded concentrations in reference sediments. In Alexander Reservoir, station ARS-8 had the highest concentrations of arsenic, copper, silver, and vanadium; and station ARS-9 had the highest concentration of cadmium. Maximum concentrations of nickel and selenium were found at both ARS-8 and ARS-9. Molybdenum was not detected in samples collected in Alexander Reservoir. Maximum metal concentrations in Alexander Reservoir test sediments exceeded maximum concentrations in reference sediments.

Metal concentrations in Soda Creek sediments do not exhibit a monotonic (unvarying) increase or decrease in a downstream direction. The whole-sediment metal concentrations for arsenic, cadmium, copper, nickel, selenium, and vanadium are plotted versus distance downstream of the diversion dam in Figures 5-1 to 5-6, respectively. Molybdenum was not plotted because molybdenum was not detected in most of the samples (Table 5-2). These figures were constructed using data collected during this investigation, as well as during the Phase I and II RI (Golder 1992 and 1994a). To illustrate the concentration gradient, robust locally weighted regression (Cleveland 1979) was used to generate the trend line shown on the figures. This trend line was generated using metal concentrations in sediments collected from Soda Creek, excluding data from sediments collected in Mormon Springs, Southwest Springs, and Homestead Spring that were collected during the Phase II RI. In addition to the trend line, the mean metal concentration in the reference sediments and the upper tolerance limit (UTL) are shown for comparison.

These concentration trends show there are two zones in the stream where metals show the greatest concentration: approximately 2,000 to 5,000 feet and 9,000 to 13,000 feet downstream of the diversion dam. Nickel and selenium show trend maximums in the first zone, copper and vanadium show trend maximums in the second zone, and arsenic and cadmium show peaks occurring in both zones. It is notable that copper has not been detected in either the non-contact cooling water or in groundwater (Mormon Springs) and is not considered a site constituent for Monsanto. In addition, neither arsenic nor nickel have been detected in the non-contact cooling water.

In contrast to metal concentrations in Soda Creek sediments, metal concentrations in sediments collected from the mouth of Soda Creek in Alexander Reservoir do show a relatively monotonic decrease with increasing distance from the mouth of Soda Creek. Metal concentrations are plotted versus relative distance from the mouth of Soda Creek in Figures 5-7 to 5-13. The mean (and the UTL) of the reference samples are also plotted for comparison. Except for cadmium, metal concentrations in sediments became less than the UTL as distance from Soda Creek increases.

Metal concentrations in sediment cores collected from Soda Creek and Alexander Reservoir are shown in Table 5-4. Bottom conditions in both the stream and the reservoir limited the sampling depth to approximately the upper foot of sediment. Difficult coring conditions (e.g., limited sediment depth overlying rock or coarse gravels) made it impossible to collect all of the sediment cores from Soda Creek identified in the sampling plan. The collected cores are sufficient to illustrate general trends in metal concentration with depth along the longitudinal profile of Soda Creek. In cores collected from Soda Creek, metal concentration with depth is relatively constant except for nickel at SCC-3; cadmium, copper, and selenium at SC-2; and cadmium, copper, and selenium at SC-5. Except for nickel at SCC-3, metal concentrations were higher in the surface sample that at depth. In cores collected from the reservoir, only concentrations of silver, selenium, and vanadium at ARC-6 showed an increase with depth.

Results of surface water characterization are shown in Table 5-5. Constituents measured in surface water samples from Soda Creek were highest at sample station SC-2, except for cadmium and hardness. Hardness was highest at sample station SC-3 and cadmium was highest at sample station SC-6. The influence of Soda Creek on measured constituents in Alexander Reservoir is evident in the different chemistry of samples from sample station ARS-9 compared to sample station ARS-2. Water collected from ARS-2 is similar to samples collected in the reference area (ARC-3 and ARC-6). Water collected at sample station ARS-9 is similar in composition to water collected at sample station SC-6.

Mean concentrations, on a clay-weight basis, are shown in Tables 5-6 and 5-7 for samples from the creek and the reservoir, respectively. For Soda Creek, the MANOVA and each ANOVA showed significant differences ($p<0.0001$) among Soda Creek sample stations for all metal constituents. Results of the Tukey-Kramer multiple comparison tests for the ANOVA are Figures 5-14 through 5-20 for each chemical constituent. Those mean concentrations with non-overlapping error bars show significant differences. For example, in Figure 5-14 the mean arsenic concentration (clay-weight basis) is significantly higher at station SC-2 as compared to stations SC-1, SCC-1, SCC-2 and SCC-3, but is not significantly different from all the other stations. The mean concentration (clay-weight basis) of arsenic, copper, nickel, selenium and vanadium in the sediments are significantly elevated at some sampling stations in Soda Creek compared to the reference loactions. However, the farthest downstream sampling station (SC-7) is not significantly different from one or more of the reference sampling stations for these metals. Only cadmium and silver have significant differences in the means of the sample station farthest downstream (SC-7) and the reference sampling stations.

For Alexander Reservoir, the MANOVA showed a significant difference ($p < 0.0001$) in the group means when considered simultaneously across all the metal constituents and pH. The results of the ANOVA and Dunnett's multiple comparison test for each metal and pH are shown in Table 5-8. This table shows there are significant difference between the group means for all the metals and pH. The multiple comparison tests for differences between the reference group and group 3 (closest to Soda Creek) are significant for all the chemical constituents ($p \leq 0.001$) and pH ($0.01 < p \leq 0.05$). The multiple comparison tests for differences between the control group and group 1 (farthest from Soda Creek) are not significant for copper and pH, and the significance level of the differences have decreased for many of the other metals relative to the test between the control group and group 3. As seen in Table 5-7, for all the metals, the concentrations are decreasing as the distance increases from the mouth of Soda Creek.

5.2 Benthic Community

Tables 5-9 and 5-10 give the mean and standard deviation for each of the benthic organisms, total number of invertebrates and number of taxa in Soda Creek and Alexander Reservoir, respectively.

5.2.1 Soda Creek

5.2.1.1 Benthic Habitat

Soda Creek was characterised by two major types of invertebrate habitat: deposional and erosional. Since Soda Creek has a relatively low gradient, the predominant habitat type was depositional, characterised by slow currents, variable aquatic macrophyte cover and mostly fine depositional sediments overlain by varying amounts of organic material. Erosional areas consisted of riffles with sand/gravel/cobble substratum and moderate current velocity and were relatively scarce, which is reflected in the lower number of samples from this habitat type. The habitats at each sampling location are described in greater detail in the following sections (ordered from upstream to downstream).

<u>Reference Reach 3</u>

This reach extended from the headwaters in the Five-Mile Meadows downstream to a point of distinct change in stream gradient. The lower boundary of the reach was located at the top of the first hydraulic control (riffle) observed to occur downstream of the headwaters. The depositional sampling site (SCC-3; Figure 4-1) was located approximately 20 m upstream of the head of this riffle. There was no erosional sampling site within this reach.

The upper portion of this reach is dry. The portion of the stream in the reach with flowing water consisted of fairly uniform habitat. The stream had a very low gradient, consisting of a slow and wide channel with no hydraulic controls or riffle habitat. The stream was approximately 20 -feet wide and three to four feet deep in the thalweg. Habitat types were limited to slow run/pool areas dominated by fines (particles <2 mm) throughout the width of the channel. Sediments at the sampling site in this reach (SCC-3) consisted of an unconsolidated organic layer over a firm silt/clay layer overlying the gravel streambed. Aquatic macrophytes were limited to minor development of submergent cover along the channel periphery.

Reference Reach 2

This reach extended from the first hydraulic control (Reference Reach 3 lower boundary) downstream to the inlet to Soda Reservoir.

The stream within this reach was approximately 15 to 25 feet wide and greater than four feet deep in the thalweg. There was a good volume of flow through this reach with a noticeably higher gradient than Reference Reach 3. Habitat consisted of a series of run/riffle areas with some backwater habitat. The stream is as wide as in Reference Reach 3 and is much wider than the stream channel downstream of the reservoir. The riffle areas consisted of bedrock/boulder/cobble substrates with fairly high velocities. Sediment deposition was still significant along the stream periphery, and in backwater and velocity break areas. Aquatic macrophytes (submergent) were well developed in the backwater areas and in the slower run habitats.

The depositional sampling site (SCC-2) in this reach was located immediately (150 ft) upstream of the reservoir inlet (Figure 4-1). The channel at this location was deep and slow due to the baclwater effects of the reservoir water, however, there was still a small amount of current at the site. The channel was very steep sided and dropped off quickly, with almost no macrophyte cover in the minor littoral area. There was heavy deposition of organic material and extensive sediment deposition in this area that consisted primarily of silt/clay (<0.5 mm).

The erosional site was located approximately 250 ft upstream of the depositional site, in the first riffle area above the reservoir. It was a bedrock/boulder/cobble riffle with a high gradient and swift velocity. The sampling site was located in the riffle tail, where the substrate was small enough (cobble) to sample with the Surber.

Reference Reach 1

This reach extended from the outlet of Soda Reservoir downstream to the diversion return located between Hooper Springs and the Monsanto non-contact cooling water outfall.

Nearly 100% of the discharge from Soda Reservoir was diverted at the Soda Reservoir outlet to a diversion canal for Powerhouse #4. The natural streambed below the reservoir contains water from inflow springs, beginning as a slow trickle that increases in volume downstream, as the inflows occur.

Within this reach the stream is approximately three to five feet wide and less than one-foot deep. There was a very low volume of flow in this reach and the natural channel was much smaller and narrower than the reaches upstream of the reservoir. Throughout the reach, most of the stream width had a heavy macrophyte cover. This cover consisted primarily of floating-leaved aquatic plants that were rooted in the stream bank, but cover most of the stream channel. There was heavy sediment deposition in all low velocity areas, including the entire stream width peripheral to the thalweg channel. Most of the flow velocity is in the stream thalweg, creating a narrow central channel with lesser sediment deposition and some exposed gravels.

The two sampling sites were located upstream of Hooper Springs, in a section of the stream which was typical of the reach. The depositional sampling site SCC-1 was located upstream of the Hooper Springs inflow in a small backwater area located near Hooper Springs Park. The erosional site was immediately upstream of the depositional site and was situated in the stream thalweg, that was free of macrophytes.

Sample Reach 1

This reach extended from the Monsanto outfall downstream to a tributary inflow (Mormon Springs). The upper reach boundary also corresponds to the headworks of the diversion #2 which diverts the entire flow of Soda Creek to a second irrigation/powerhouse canal.

The stream within this reach has a width of two to four-feet and a depth of less than one-foot. This reach has a very low flow volume with water in the natural channel coming from groundwater inflows. Sample Reach 1 had numerous meanders and one inflow channel located upstream of Mormon Spring. The stream channel was narrow and almost completely covered by floating-leaved aquatic macrophytes. There was considerable deposition of fines throughout the channel. Some sections of the channel thalweg with slightly higher flow velocities consisted of a narrow strip of gravel/sand surrounded to the periphery with fines and macrophytes.

The depositional sampling site (SC-1) was located immediately upstream of the Mormon Spring inflow channel in an area of sediment deposition that was free of macrophytes. The erosional sampling site was located in the stream thalweg immediately upstream. The sediments at the depositional sampling site were sandy.

Sample Reach 2

This reach extended from the Mormon Springs inflow channel downstream approximately 1,000 feet.

The habitat within Sample Reach 2 was the same as that in Sample Reach 1. Both sections were fairly short segments of meandering stream, separated by the inflow of Mormon Springs.

The depositional sampling site (SCC-2) was located upstream and around the first meander bend from the lower reach boundary. It was situated in an area of heavy sediment deposition that did not have significant macrophyte cover. The erosional site is located immediately upstream, in the channel thalweg. As in Sample Reach 1, the sediments were sand-sized particles.

Sample Reach 3

This reach extended from the bottom of Sample Reach 2 (Reach 2) downstream to the Soda Springs Town limits.

This reach had a very low flow volume with habitat similar to Sample Reaches 1 and 2. The stream channel was noticeably less meandering with a lesser amount of sediment deposition than in Sample Reaches 1 and 2. The stream was almost completely covered by emergent and submergent (floating-leaved) plants that were rooted along the sides of the thalweg. The fines were more to the periphery of the thalweg than in Sample Reaches 1 and 2. There was a noticeable thalweg channel with gravel/cobble substrate and occasional small boulders, that occurred over a broader area than in Sample Reaches 1 and 2. As in Sample Reaches 1 and 2, there was no riffle habitat or any areas deep enough to comprise pool habitat.

The depositional sampling site is located just upstream of the lower reach boundary. There are no good areas of sediment deposition which are also without macrophyte cover. The sampling site is in very shallow water with cover from short, grass-like macrophytes. The erosional site is located immediately upstream in the thalweg channel.

Sample Reach 4

This reach extended from a point beginning 300 ft downstream of the Reach 3 lower boundary to the Powerhouse #5 diversion return. The short section (approximately 300 ft) omitted from the reach designation process consisted of a long, straight bedrock run with a higher gradient than either Sample Reach 3 or 4. It was both brief and considered atypical.

There was very low flow volume and habitat in this reach similar to Sample Reach 3 with a somewhat wider thalweg channel. There were no portions that could be classified as true riffle habitat. Deposition of fines occurs to the periphery of the thalweg channel. The gradient in Sample Reach 4 was slightly higher than in Sample Reach 3.

The depositional sampling site (SC-4) was located immediately upstream of the lower reach boundary in a wider, deeper pool section. The erosional site was located immediately upstream in the thalweg channel.

Sample Reach 5

This reach extended from the Powerhouse #5 discharge downstream to the headworks of Soda Canal.

This was the first reach downstream of Soda Reservoir to carry the full discharge of the creek system. It is the reach with the highest flow volume, and the channel is full in places to the top of the banks. Habitat types included long sections of deep run habitat interrupted by regular riffle areas with some backwater habitat.

The channel is wider and better defined than Sample Reaches 1 to 4 due to the high flow rate. This stream was approximately five- to ten-feet wide with a depth of three- to five-feet in the thalweg. Despite the higher discharge there was still considerable deposition of fines along the periphery of the stream thalweg and an extensive macrophyte cover along the stream periphery that occasionally extended the width of the stream. The aquatic macrophytes present in this reach are primarily submergents, with few of the emergents and floating-leaved plants that were observed in Sample Reaches 1 to 4. The thalweg channel for the most part was free of macrophytes and consisted of a mixture of gravels/fines for substrate. Riffle-like hydraulic control sections occur regularly which are dominated by boulders together with submergent macrophytes.

The depositional sampling site (SCC-5) was situated in a shallow area between the bank and a small vegetation island, located well upstream of the lower reach boundary. This area was selected because of the lesser development of macrophyte cover. The erosional sampling site was located immediately downstream of a bridge crossing in a small gravel patch at the periphery of a riffle area.

Sample Reach 6

This reach extended from the Soda Canal diversion downstream to the upstream side of the railway crossing culvert (Figure 4-1).

At the time of sampling a small (approximately 10%) portion of the Soda Creek flow was being diverted into Soda Canal. Therefore, Sample Reach 6, like Sample Reach 5, had a high flow rate, although not bankfull. This reach had a moderately high gradient and swift flow velocity similar to Sample Reach 5.

The habitat in Sample Reach 6 is similar to Sample Reach 5, with deep/fast run habitat and regular riffle areas and backwater habitat. There was heavy deposition of fines along the periphery of the thalweg with extensive development of submerged macrophytes along the periphery and, in places, throughout the stream width. Riffle areas were dominated by boulders with complete coverage by macrophytes.

The depositional sampling site (SC-6) was located upstream and around a bend from the lower reach boundary in a small backwater pocket. The backwater area was largely macrophyte free and shallow enough to sample. The erosional site was difficult to locate due to the depth and velocity of the thalweg channel. It was located well upstream (~650 ft) of the deposition site in the thalweg channel at a spot that was shallow enough to sample.

Sample Reach 7

This reach extended from the railway crossing culvert (Figure 4-1) downstream to the creek mouth (confluence with Alexander Reservoir).

This reach had the same flow volume as Sample Reach 6 with similar habitat characteristics. It was dominated by deep/swift run areas with regular riffle sections. There was no distinct pool habitat, but some areas of backwater habitats were present, particularly on meander bends. There was heavy deposition of fines along the thalweg periphery and in backwater areas with a well developed cover of submerged macrophytes. Riffle areas were dominated by boulders and were completely covered by submergent macrophytes.

The depositional sampling site (SC-7) was located in a backwater pocket on the first bend upstream of the creek mouth. The erosional sampling site was located upstream (~ 150 ft), in the first area in the thalweg channel that was shallow enough to sample.

5.2.1.2 Data Analysis

Depositional areas of Soda Creek supported 11,000 to 102,000 invertebrates per square meter. A total of 33 taxa were identified from depositional sites. As in the reservoir, the benthic fauna was dominated by oligochaete worms and chironomid midge larvae, which collectively accounted for 97.3% of mean total invertebrate density. Taxonomic richness (number of taxa encountered) at individual sites ranged from means of 4.3 to 5.7 at the reference sites and from 6 to 10.3 at the sample sites.

The MANOVA showed significant differences in the means (of the $\log_{10}$ transformed data) of the benthic invertebrates, total invertebrates and taxa between the Soda Creek sample stations ($p < 0.0001$). A canonical correlation was performed to determine if there was an association between the metal concentrations and benthic fauna. The CCA used the $\log_{10}$ transformations of Tubificidae, Tantytarsini, Orthocladiinae, *Chironomus* sp., Tanypodinae, and total invertebrates together with the number of taxa. The first set of canonical covariates had a squared canonical correlation of 0.84 ($p < 0.0001$) and the second canonical covariates had a squared correlation of 0.66 ($p = 0.0189$). The other sets of canonical covariates were insignificant.

Table 5-11 shows the canonical coefficients for the first two sets of canonical covariates. The first set of canonical covariates is dominated by Tubificidae, Total Invertebrates, silver and vanadium. As the concentration of silver increases, the number of Tubificidae decrease but the total number of invertebrates increase. Conversely, as the concentration of vanadium increases, the number of Tubificidae increase but the total number of invertebrates decrease. The second set of canonical covariates are dominated by Tanytarsini, number of taxa, cadmium, nickel, and vanadium. As the concentration of cadmium and vanadium increases, the number of Tanytarsini and taxa increase, while as the concentration of nickel increases, the number of Tanytarsini and taxa decrease. Figures 5-21 and 5-22 show the plots of the first and second sets of canonical covariates, respectively. As seen in Figure 5-21, the first set of canonical covariates separates stations SC-6 and SC-7 from the other stations. The remaining stations, both sample and reference, are in no distinguishable groupings. As seen in Figure 5-22, the second set of canonical covariates separates station SCC-1 from all the other stations, which do not show any distinguishable groupings.

The CCA develops the most significant statistical associations between metal concentrations and benthic fauna attributes. These statistical associations are far more significant than any single multiple regression of metal concentrations on individual benthic organisms. For example, the most significant multiple regression is on Tubificidae (R-square = 0.55) and shows that the increasing numbers of Tubificidae are associated with decreasing concentrations of silver and cadmium and increasing copper concentration. However, the biological appropriateness of the associations and whether they indicate a degradation in the benthic community is a matter of interpretation. Information from Table 5-11, Figures 5-21 and 5-22, and the original data given in Table 5-9 must be simultaneously considered when interpreting the results of the CCA.

The most striking result of the first set of canonical covariates is the large separation of sites SC-6 and SC-7 from the other sites on Soda Creek. Both of these sites get large negative metal canonical covariates because of the relatively high concentrations of silver and relatively low concentrations of vanadium and copper. However, the large negative benthic canonical covariates for these two sites are based on radically different benthic communities. At site SC-6, the number of Tubificidae is almost an order of magnitude smaller than all the other sites, except SC-7. However, site SC-7 has a large negative benthic covariate due to the large total number of invertebrates at that site, which is dominated by Chironomini (two orders of magnitude greater than at any other site). Thus, these two sites, with similar metal concentrations have very different benthic communities, and both of these benthic communities are very different from all the other sites.

The second set of canonical covariates separates the reference site SCC-1 from all the other sites. The large negative metal canonical covariate is due to the relatively high concentration of nickel at this reference site and the low concentration of all other metals. The large negative benthic canonical covariate is due to the absence of Tanytarsini, the relatively small number of taxa and the large number of total invertebrates (almost all of which are Tubificidae).

The CCA has in essence shown that sites SCC-1, SC-6 and SC-7 have different benthic communities than the other sites. It has associated these differences with linear combinations of the metal concentrations at those sites which will also distinguish them from the other sites. However, these differences can also be due to changes in habitat that are unrelated to the metal concentrations and the association with the metal canonical covariate is an artifact of the CCA. To help determine if there is a relationship between metal concentration and benthic fauna, the MANOVA was performed again with the these three sites removed. The seven remaining sites include two reference sites, and the sample sites with the highest metal concentrations. The MANOVA was again significant ($p=0.0127$) although not as significant as before when $p < 0.0001$. This significant difference was due to differences in Tanytarsini and Tanypodinae. The differences are again isolated at specific sites, the small number of Tanytarsini at sites SC-2 and SC-3 relative to the other sites, and the large number of Tanypodinae at SC-5 relative to the other sites. The dominant species at all these sites, Tubificidae, is not significantly different. For both of these benthic invertebrates, the reference sites, SCC-2 and SCC-3, are not significantly different from most of the sample sites, which indicates that these differences are not associated with the elevated metal concentrations at the sample sites. Therefore, it is concluded that while there are significant differences in the benthic fauna between the sites, the differences are not associated with metal concentrations.

Erosional sites (Table 5-12) were characterised by slightly more diverse but less abundant invertebrate communities. Total taxa at these sites amounted to 22 with 9 and 12 taxa at two the reference sites and 7 to 13 taxa at the sample sites. Total invertebrate density was 17,800 and 19,400 and similar at the reference sites, but varied greatly at the sample sites (2,800 to 38,800). The benthic fauna of erosional sites was also dominated by oligochaete worms and chironomids that accounted for approximately 82% of total invertebrates, but also included mayfly nymphs, caddisfly larvae, leeches, amphipods and other taxa at lower densities. Densities of each taxon varied greatly among sites and as a consequence, consistent differences between the control and sample sites were absent.

5.2.2 Alexander Reservoir

The benthic invertebrate sampling sites were located in the two eastern arms of the reservoir (Figure 4-1). Sites were characterised by 1.5 to 5 feet depth and soft mud substratum. Aquatic plants were absent from the areas sampled. All reservoir sites were located in comparable habitats.

The bottom fauna of Alexander Reservoir was dominated by oligochaete worms (mostly Tubificidae) and chironomid midge larvae (especially *Chironomus*), which collectively accounted for means of 98.3 and 99% of total invertebrates at the control sites and below Soda Creek, respectively. Total invertebrate density ranged from 1,600 to 8,300 individuals per square meter at the control sites, compared with 3,800 to 27,800 individuals per square meter in the reservoir arm below the inflow from Soda Creek. Taxonomic richness (total number of taxa) in the control sites and sample sites had mean values of 7.9 and 9.3, respectively.

The MANOVA was insignificant ($p=0.5115$), thus the null hypothesis of equality of means (of the $\log_{10}$ transformed data) of the groups is not rejected. There is no statistical evidence of a difference in the benthic fauna across all the groups. It should be noted, that the MANOVA was actually run on several different transformations of the data and included all the benthic invertebrates, in all cases the MANOVA showed no significant differences. Additionally, the univariate ANOVAs also showed no statistical evidence of a difference in the benthic fauna across all the groups. Therefore, the sediment chemistry in Alexander Reservoir is not associated with any changes in the benthic fauna.

5.3 Toxicity Testing

Table 5-13 shows the mean and standard deviation for the percent mortality and dry weight (mg/organism) for each sample station or group in the creek and the reservoir.

For sediment samples collected in Soda Creek there was not a significant difference ($p=0.3384$) between the mean percent mortality of the locations (which includes the laboratory controls). There was, however, a significant difference ($p=0.0009$) between the mean dry weight per organism at the locations. The primary significant difference is the dry weight of the laboratory controls is significantly smaller than the dry weights at station SCC-3 ($p \leq 0.001$), SCC-1 ($0.001 < p \leq 0.05$) and SC-6 ($0.001 < p \leq 0.05$). The only significant difference between stream sample locations is the dry weight at SC-7 is significantly lower than at SCC-3.

For sediment samples collected in Alexander Reservoir there was not a significant difference ($p=0.1465$) between the mean percent mortality of the locations. There was, however, a significant difference ($p \leq 0.0001$) between the mean dry weight per organism of the locations. Table 5-14 shows the significant pairwise differences in mean dry weights from Tukey's multiple comparison tests. As seen in Table 5-13, Groups 2 (ARS-4, 5, and 6) and 3 (ARS-7, 8, and 9) have a significantly lower dry weight than the reference samples. However, the laboratory control also has a significantly lower dry weight than the reservoir reference samples. This indicates that the lack of growth (i.e. lower dry weight) may be due to a lack of suitable food, rather than metal toxicity.

6. DISCUSSION

To evaluate sediment quality in Soda Creek and Alexander Reservoir an effects-based approach has been adopted, rather than rely on surrogate sediment quality guidelines (e.g., Ecology 1991). The effects-based approach for this study will incorporate the measures of sediment chemistry, sediment toxicity, and benthic community structure, also known as the sediment quality triad (Triad) approach (Chapman 1992). The Triad approach is intended to allow for (1) interaction between constituents in complex sediment mixtures (e.g., additivity, antagonism, synergism), (2) potential actions of unidentified chemicals, and (3) effects of environmental variables that may influence biological responses (e.g., toxicant concentrations and bioavailabity) (Chapman 1992). The three components of the Triad approach provide complementary data for a site-specific ecological assessment of endpoints that are relevant to the evaluated ecological resources (Soda Creek and Alexander Reservoir. In this study, the Triad data have been evaluated using analysis of variance, and canonical correlation analysis to determine if there are any consistent and significant relationships among the data.

Sediment quality guidelines depend on chemical measures and anticipated effects to ecological resources. The chemical measures incorporated into sediment quality guidelines do not adequately integrate the effects that sediment conditions (e.g., grain size, organic content, pH, oxidation-reduction state, chemical form, etc.) have on toxicity. In addition, the ecological effects evaluated using sediment quality guidelines are unknown and may be inappropriate for the evaluated system. Consequently, sediment quality guidelines developed for other localities are not appropriate for this assessment of Soda Creek and Alexander Reservoir.

6.1 Soda Creek

The mean concentration (clay-weight basis) of arsenic, copper, nickel, selenium, and vanadium are significantly elevated at some downstream sample stations in Soda Creek compared to the reference sample stations. However, for these metals the farthest downstream sample station for Soda Creek (SC-7) is not significantly different from one or more of the reference stations. Only cadmium and silver have significantly different mean concentrations at all sampling stations relative to the reference stations. Silver is not detected in either the Monsanto non-contact cooling water or groundwater from Mormon Springs

Spatial trends in concentration show two principal areas where these metals are accumulating relative to reference samples: (1) 2,000 to 5,000 feet and (2) 9,000 to 13,000 feet downstream of the diversion dam on Soda Creek. Non-contact cooling water is not a likely source for elevated metal concentrations in sediments found in either zone of accumulation. Non-contact cooling water from Monsanto does not actually enter Soda Creek until passing through the powerhouses located approximately 5,000 to 6,000 feet downstream of the diversion dam on Soda Creek. The spatial distributions of metal concentrations do not show peaks that would be associated with the powerhouse return flow. Metal accumulations in the first area are probably related to groundwater discharges from Calf/Mormon Springs, which enters Soda Creek approximately 1,500 feet downstream of the diversion dam on Soda Creek. The source of metals for the second area of accumulation is unknown, but is likely related to other sources of discharge within the City of Soda Springs not related to the Monsanto facility.

The numbers of organisms found in Soda Creek sediments ranged from 11,000 to 102,000 invertebrates per square meter. The benthic fauna at all stations (sample or reference) was dominated by oligochaetes and chironomids. The taxonomic richness was slightly higher at sample sites relative to the reference sites. The dominance of the benthic community by oligochaetes and chironomids is characteristic of depositional habitats with a potential for oxygen depletion in the sediment (Wiederholm 1984) and are indicative of low quality aquatic habitat that receive high loadings of organic material or nutrients.

MANOVA showed there were significant differences in the means of (1) different benthic invertebrates, (2) total numbers of invertebrates, and (3) number of taxa at the stations. Canonical correlation analysis showed that there were significant differences in the benthic fauna at three sites: SCC-1, SC-6 and SC-7. The association of the significant differences in benthic fauna with metal concentrations in the sediments appear to be artifacts of the CCA. When the MANOVA of the benthic fauna is repeated with these three sites removed from the analysis, there are only significant differences in Tanytarsini and Tanypodinae at isolated sites. There are no significant differences between the sites for the dominant species, Tubificidae. Since these seven remaining sites include two of the reference stations and the sample stations with the highest metal concentrations, there is no significant adverse effect of metal concentrations on the benthic community.

Toxicity testing showed there was no significant difference in percent mortality between reference and sample stations. The only significant difference found for organism growth was between one sample station (SC-7) and one reference station (SCC-3). There was not a significant difference between this sample station and any other reference station. Therefore, based on the methodology used in this study the sediment samples collected from Soda Creek are considered non-toxic.

For Soda Creek, it has been shown that there are elevated levels of metals in sediments, but there has been no meaningful alteration of the benthic community structure that can be attributed to the presence of those elevated concentrations. In addition, the sediments do not exhibit toxicity to the types of organisms naturally-occurring in the sediments. Based on the Triad approach, the preponderance of evidence shows there has not been a significant impact to the benthic community structure.

6.2 Alexander Reservoir

The highest concentrations of metals are found in the group of sample stations located closest to the mouth of Soda Creek. Spatial trends indicate decreasing concentrations with increasing distance from Soda Creek. The metal concentrations in sample stations at the mouth of Soda Creek are significantly higher than metal concentrations in the reference samples. Thus, there are elevated metal concentrations in Alexander Reservoir that can be attributed to Soda Creek. However, the metal loading from Soda Creek is rapidly attenuated in the reservoir, because of the low sediment load from Soda Creek.

As in Soda Creek, the benthic fauna at both the reference stations and sample stations in Alexander Reservoir are dominated by oligochaetes and chironomids, again indicating a low quality depositional aquatic habitat subject to oxygen depletion and high loadings of nutrients and organic material. This would not be unexpected since sediment samples were collected from depths less than 5 feet below the water surface. These sites could be exposed during reservoir drawdowns, which would result in stress to the organisms. Therefore, only stress-tolerant organisms would be expected to inhabit these locations. There was no statistically significant difference between benthic community structure between any sample group and the reference group, indicating that elevated metal concentrations have not altered the community structure.

Toxicity testing showed no significant differences in percent mortality between the reference group and the sample stations. There was, however, a significant difference in growth between the reference group and the two groups of samples stations that were located closest to the mouth of Soda Creek. Notably, the group of sample stations located closest to the mouth of Soda Creek that had the highest metal concentrations did not show any evidence of toxicity relative to laboratory control sediments.

For Alexander Reservoir, there are elevated concentrations of metals in sediments collected near the mouth of Soda Creek. The presence of these metals has not resulted in an alteration of the benthic community structure. Toxicity testing shows that there is stress (i.e., lower growth) but not acute mortality resulting from exposure to toxic chemicals. It is difficult to attribute the observed toxic response to the presence of metals in the sediments because the response did not occur in the sediments with the highest metal concentrations.

7. SUMMARY AND CONCLUSIONS

Analysis of the Soda Creek sediment samples show the following:

- The benthos in both the reference and sample areas of Soda Creek are dominated by species that are indicative of a "low quality" stream system. Therefore, alterations to the benthic community structure are not considered a significant ecological impact.

- There is no significant difference in the percent mortality in toxicity tests of the test sediment samples as compared to the reference sediment samples. The dry weight of the organisms at the end of the toxicity tests were significantly lower for the test station farthest from the outfall as compared to the reference station SCC-3. However, this is the test station with the least number of significant elevations in chemical concentrations or the highest chemical concentrations.

- The benthic communities at the two sample stations farthest downstream of the diversion dam and at the reference station immediately upstream of the diversion dam have a different structure from the other stations. These differences appear to be due to local hydrologic phenomena rather than differences in metal concentrations. When these sites are removed from the analysis, the remaining seven sites (including two reference sites and the sample sites with the highest metal concentrations) do not show a significant change in benthic communities associated with the elevated metal concentrations downstream of the diversion dam on Soda Creek.

- The mean concentration of arsenic, copper, nickel, selenium and vanadium in the sediments are elevated at some of the sample stations, however, the sample stations farthest downstream are not significantly different from one or more of the reference sampling stations (background). Only cadmium has a significant difference in the means of the test station farthest downstream (SC-7) and the reference stations of the constituents detected in the Monsanto non-contact cooling water outfall or discharge from Mormon Springs.

- Other sources within the City of Soda Springs may be responsible for metal accumulation at some sample locations in Soda Creek.

Analysis of the Alexander Reservoir sediment samples show the following:

- The benthos in both the reference and sample areas of Alexander Reservoir are dominated by species that are indicative of a "low quality" system. Therefore, alterations to the benthic community structure are not considered a significant ecological impact.

- A significant increase in the concentration of arsenic, cadmium, copper, nickel, selenium, silver and vanadium in sediment samples from the area of the reservoir affected by Soda Creek as compared to the reference area. Of these, only arsenic, cadmium, nickel, selenium, and vanadium were detected in either the non-contact cooling water or groundwater discharge from Mormon Springs. The significance of this increase is greatest closest to the mouth of Soda Creek and decreases with distance from the mouth of Soda Creek, with copper and pH not being significantly different from the control area at the group farthest from Soda Creek.

- There is no significant difference in the benthic community in the sediment samples from the area of the reservoir affected by Soda Creek as compared to the control area.

- There is no significant difference in the percent mortality in toxicity tests of the sediment samples from the area of the reservoir affected by Soda Creek as compared to the reference area.

The results of using the Triad approach show that the presence of elevated metal concentrations in sediments from Soda Creek and Alexander Reservoir have not significantly altered the benthic community structure of either system. In addition, there is no evidence of toxicity in Soda Creek sediments. Sediments from Alexander Reservoir do show evidence of toxicity, however, data suggest that it is not related to metal concentration. Based on these results, no adverse ecological effects have occurred as a consequence of the discharge of non-contact cooling water and natural groundwater discharge containing metals to Soda Creek. Based on this conclusion, there is no need for further sampling of Soda Creek or Alexander Reservoir for the Monsanto RI.

8. LITERATURE CITED

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Figures

FIGURES

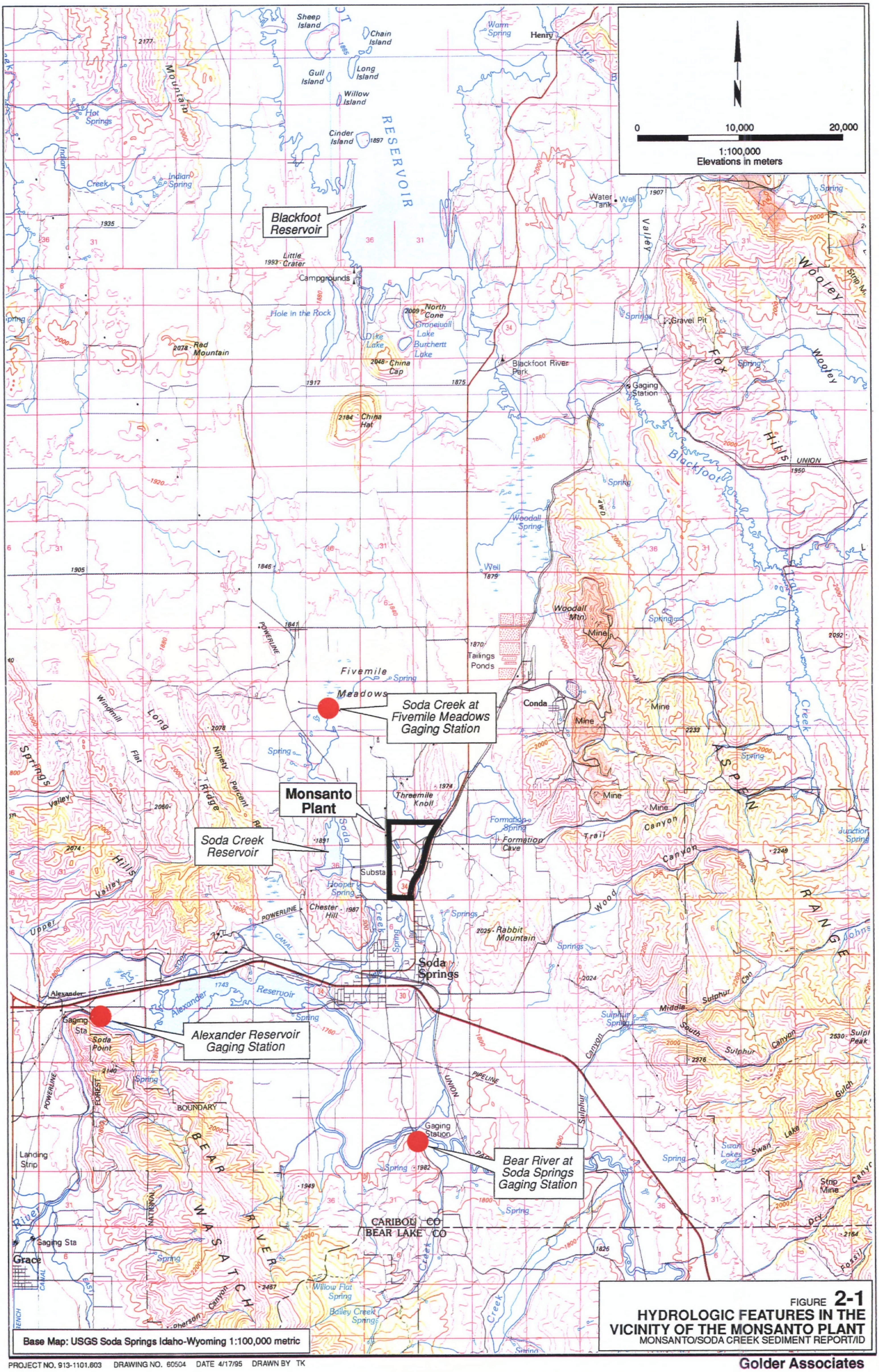


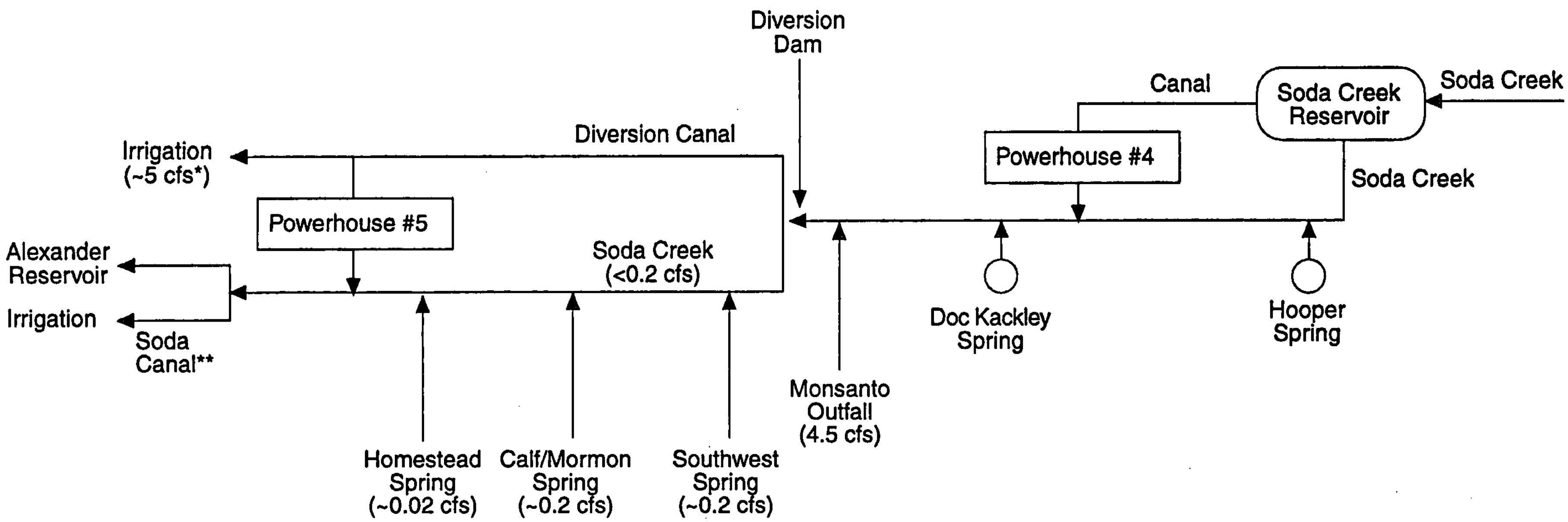
FIGURE **2-1**

HYDROLOGIC FEATURES IN THE VICINITY OF THE MONSANTO PLANT

MONSANTO/SODA CREEK SEDIMENT REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 60504 DATE 4/17/95 DRAWN BY TK

Golder Associates



NOTES

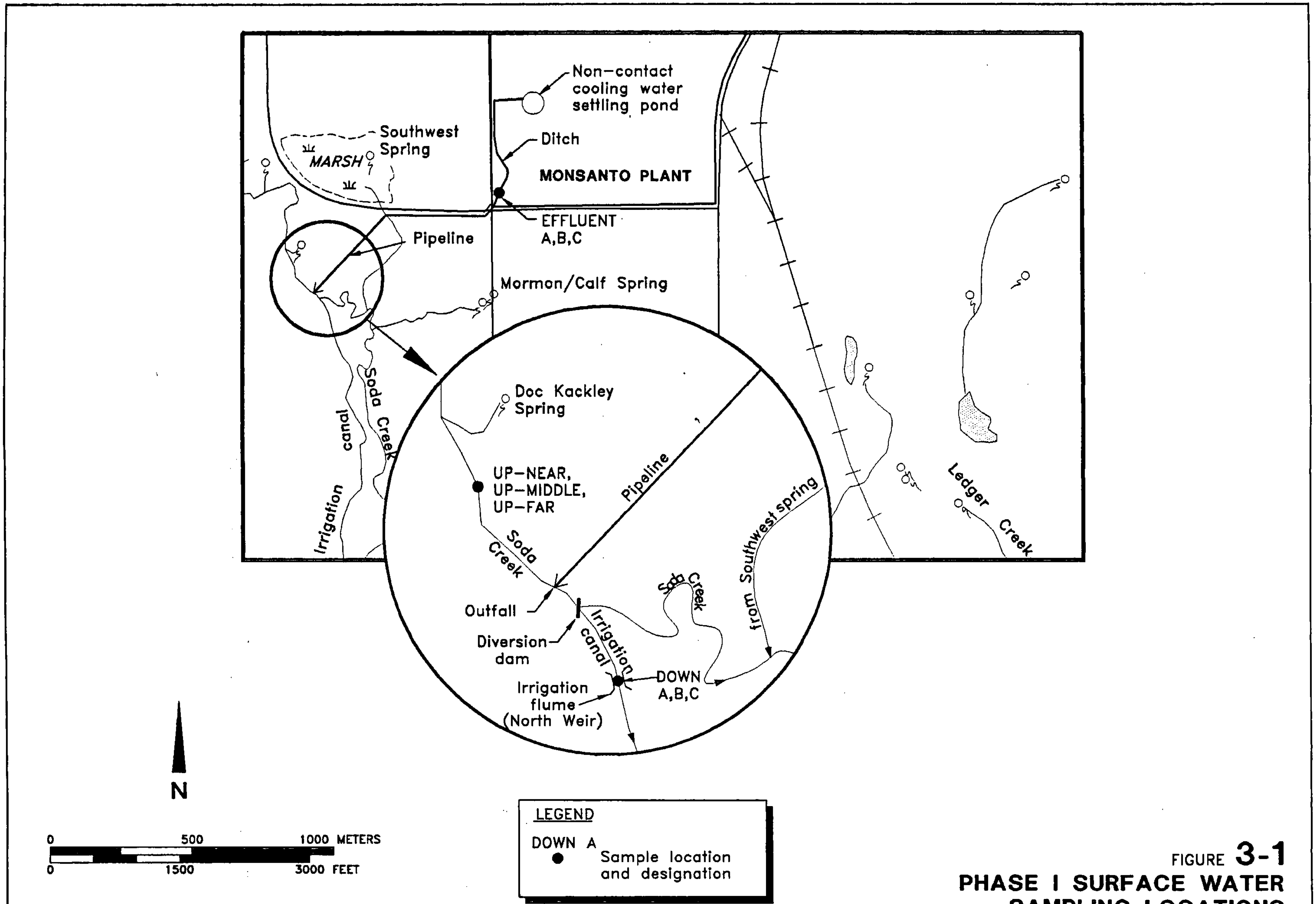
* – Only during 3-4 months of summer

** – Receives all flow during 3-4 months of summer

FIGURE 2-2
APPROXIMATE FLOW THROUGH THE SODA CREEK STREAM SYSTEM
MONSANTO/SODA CREEK SEDIMENT REPORT/ID

PROJECT NO. 913 1101.603 DRAWING NO. 60140 DATE 5/19/95 DRAWN BY EA

Golder Associates



Note: Locations are approximate.

FIGURE **3-1**

PHASE I SURFACE WATER SAMPLING LOCATIONS

MONSANTO/SODA CREEK SEDIMENT REPORT/ID

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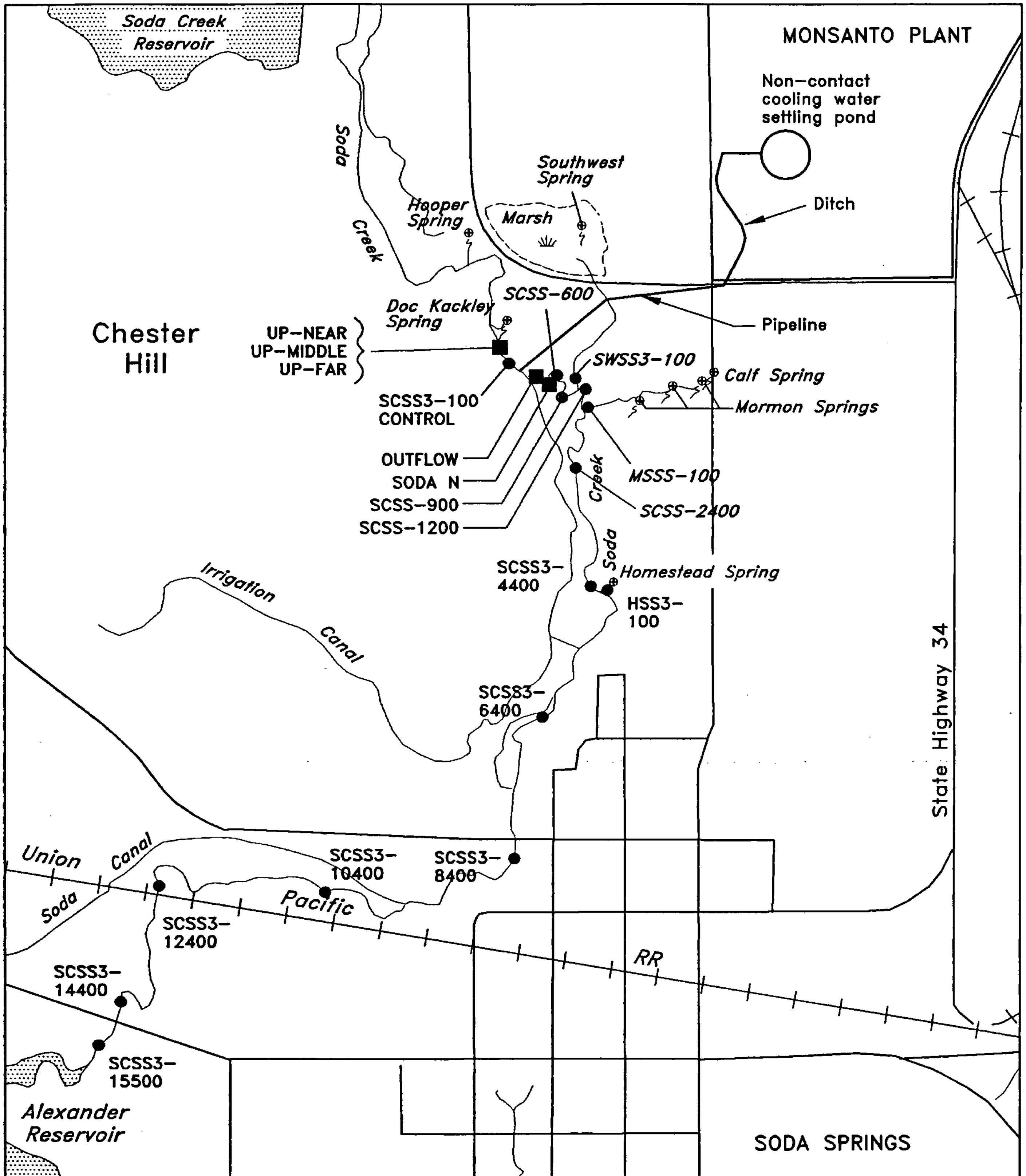
Golder Associates



LEGEND

OUTFLOW ■	Phase I sample location and designation
HSS3-100 ●	Phase II sample location and designation

Note: Locations are approximate.

FIGURE 3-2

PHASES I & II STREAM SEDIMENT SAMPLING LOCATIONS

MONSANTO/SODA CREEK SEDIMENT REPORT/ID

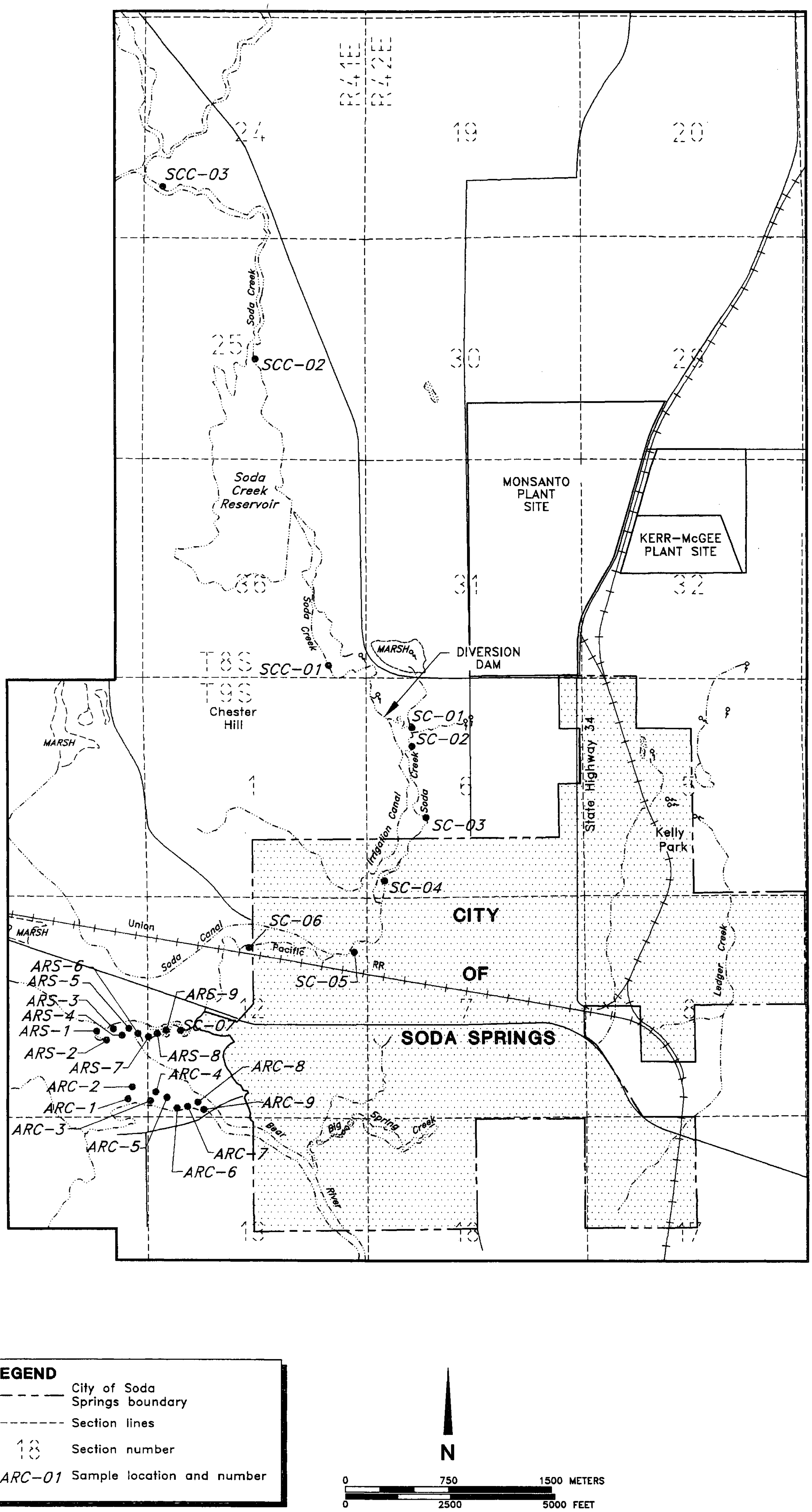


FIGURE **4-1**
SAMPLE SITE LOCATIONS FOR SODA CREEK AND ALEXANDER RESERVOIR
MONSANTO/SODA CREEK SEDIMENT REPORT/ID

C:\CAD_4\9131101\603\52224 5-19-95 15:29

Golder Associates

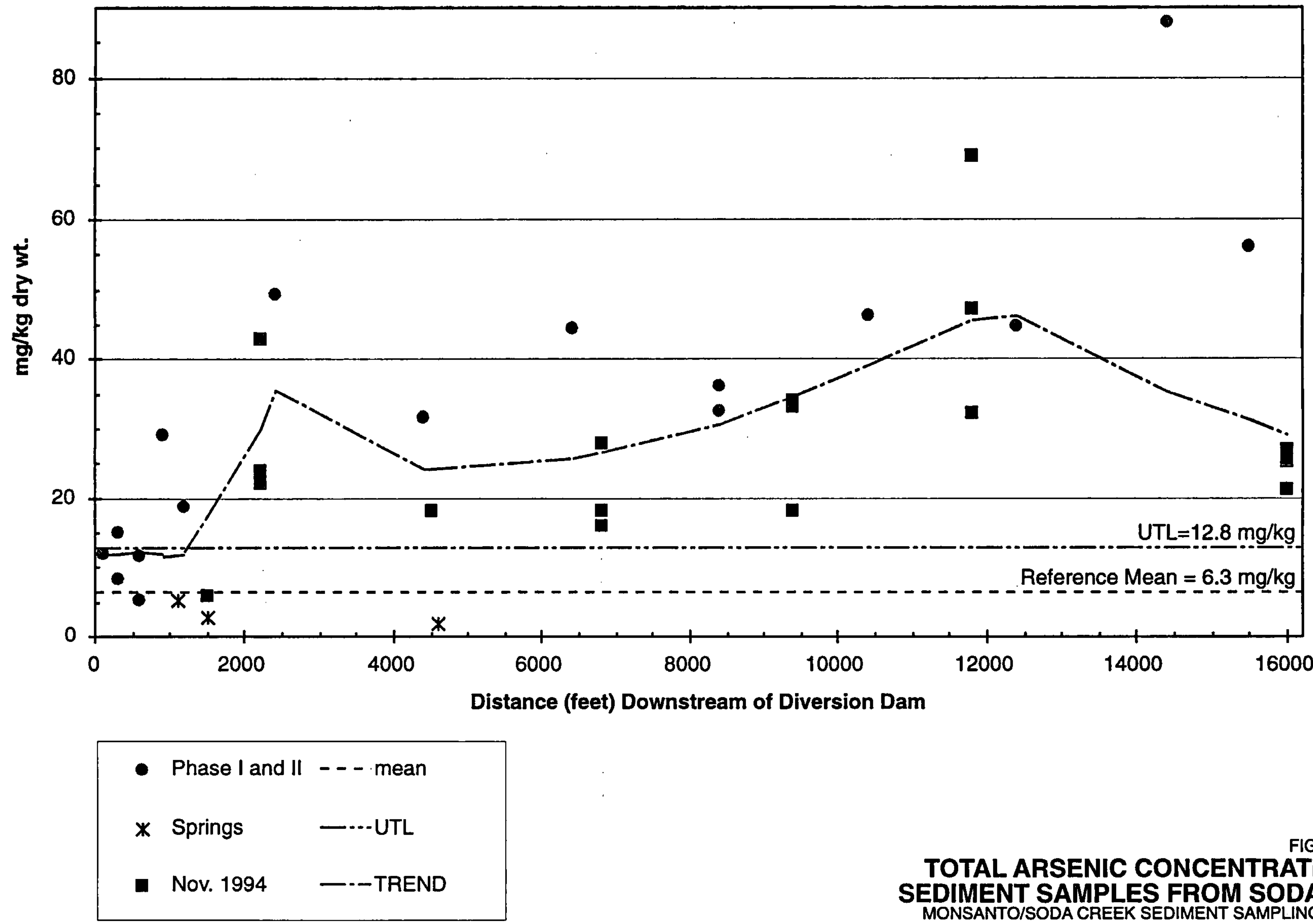


FIGURE **5-1**

TOTAL ARSENIC CONCENTRATION FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50868 DATE 5/24/95 DRAWN BY TK

Golder Associates

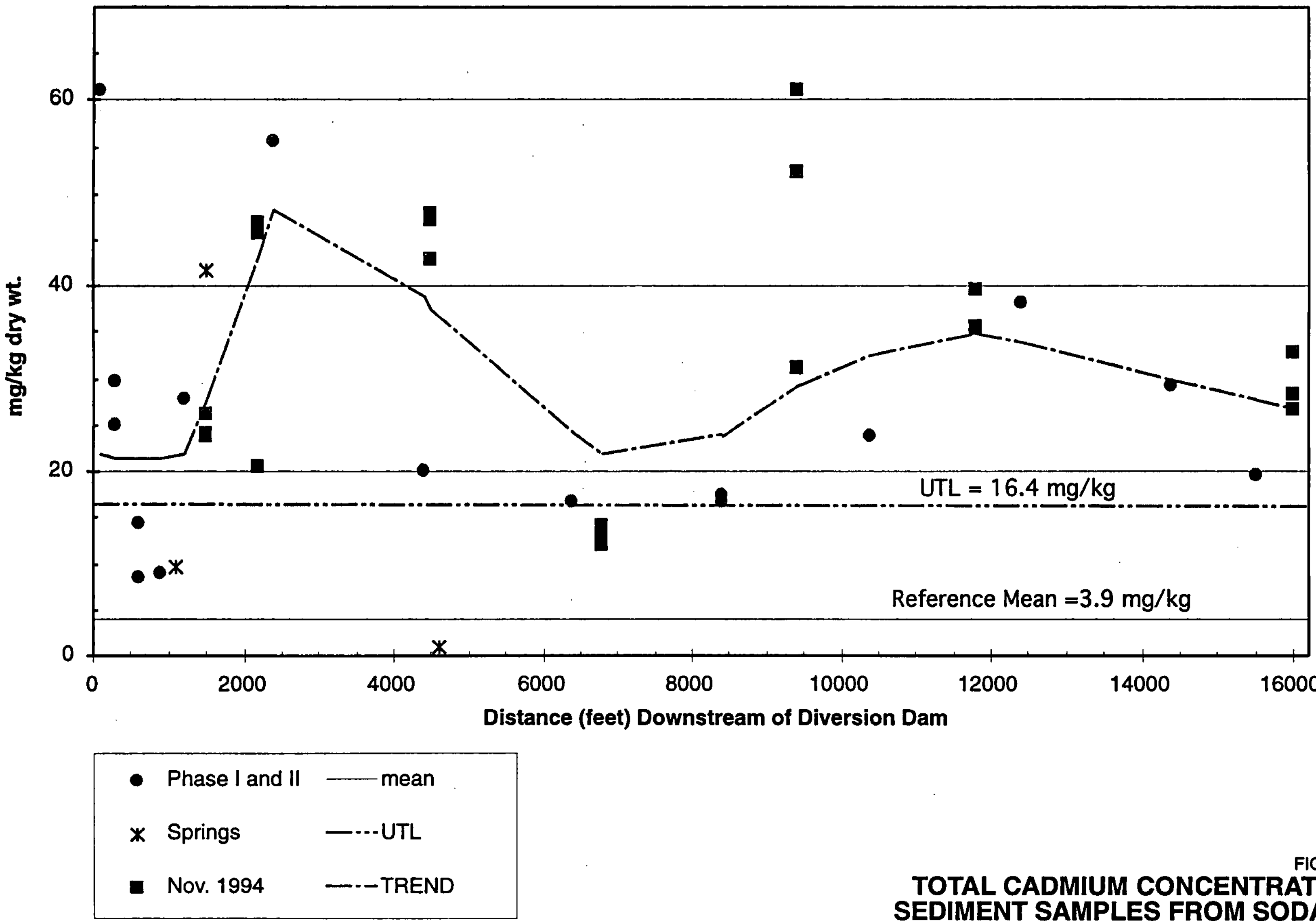


FIGURE **5-2**

TOTAL CADMIUM CONCENTRATION FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50869 DATE 5/23/95 DRAWN BY TK

Golder Associates

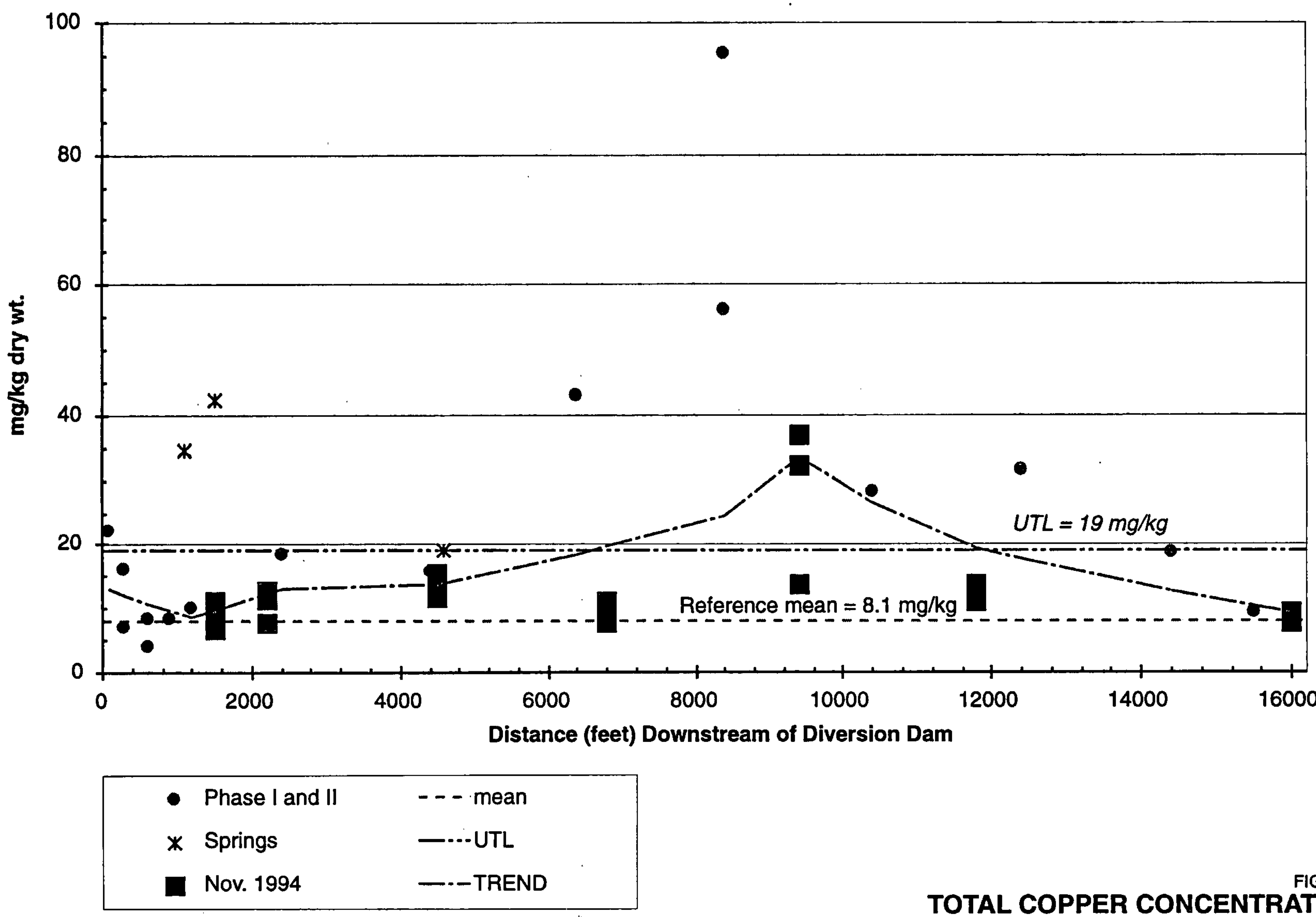


FIGURE **5-3**

TOTAL COPPER CONCENTRATION FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50870 DATE 5/23/95 DRAWN BY TK

Golder Associates

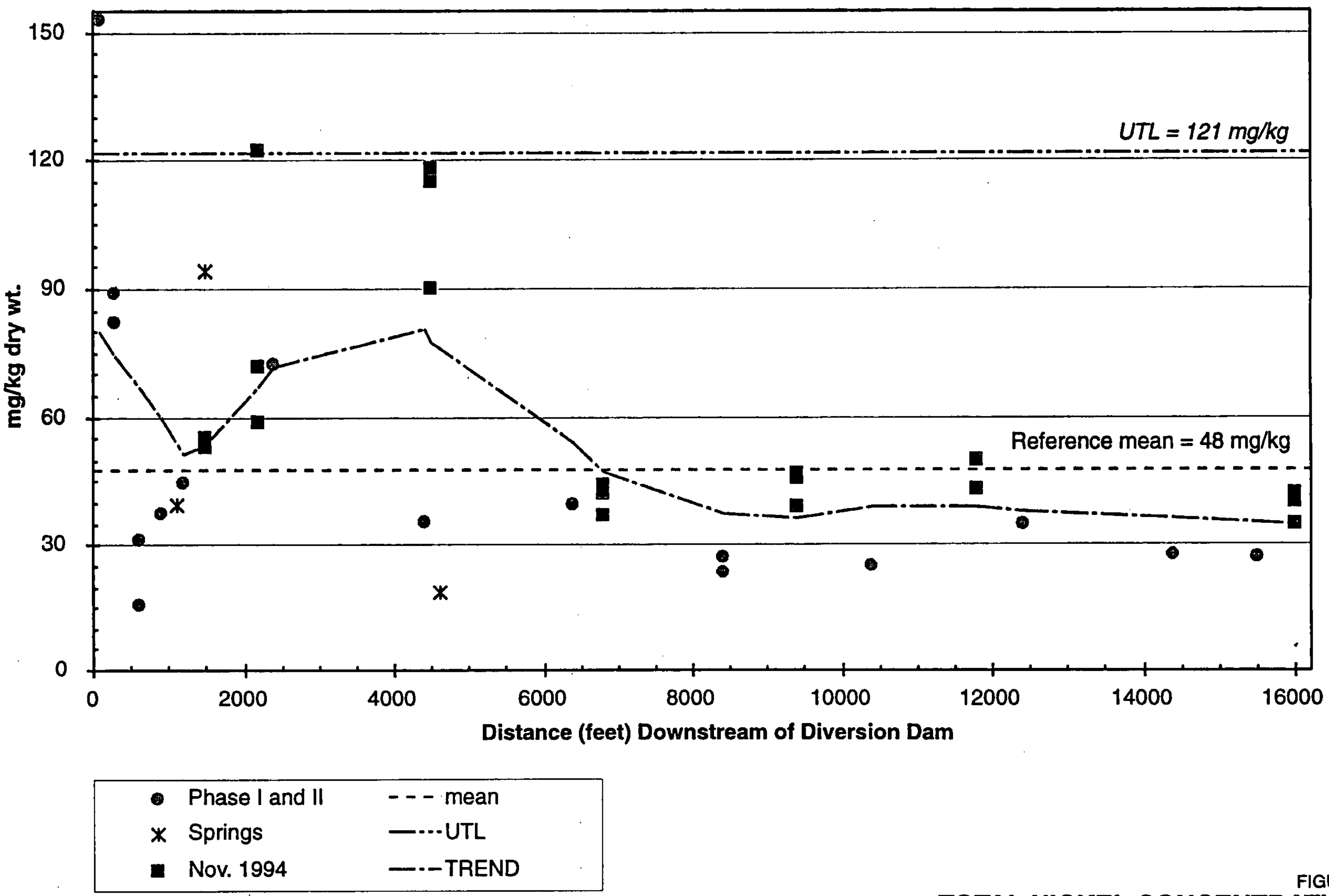


FIGURE **5-4**

TOTAL NICKEL CONCENTRATION FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50871 DATE 5/24/95 DRAWN BY TK

Golder Associates

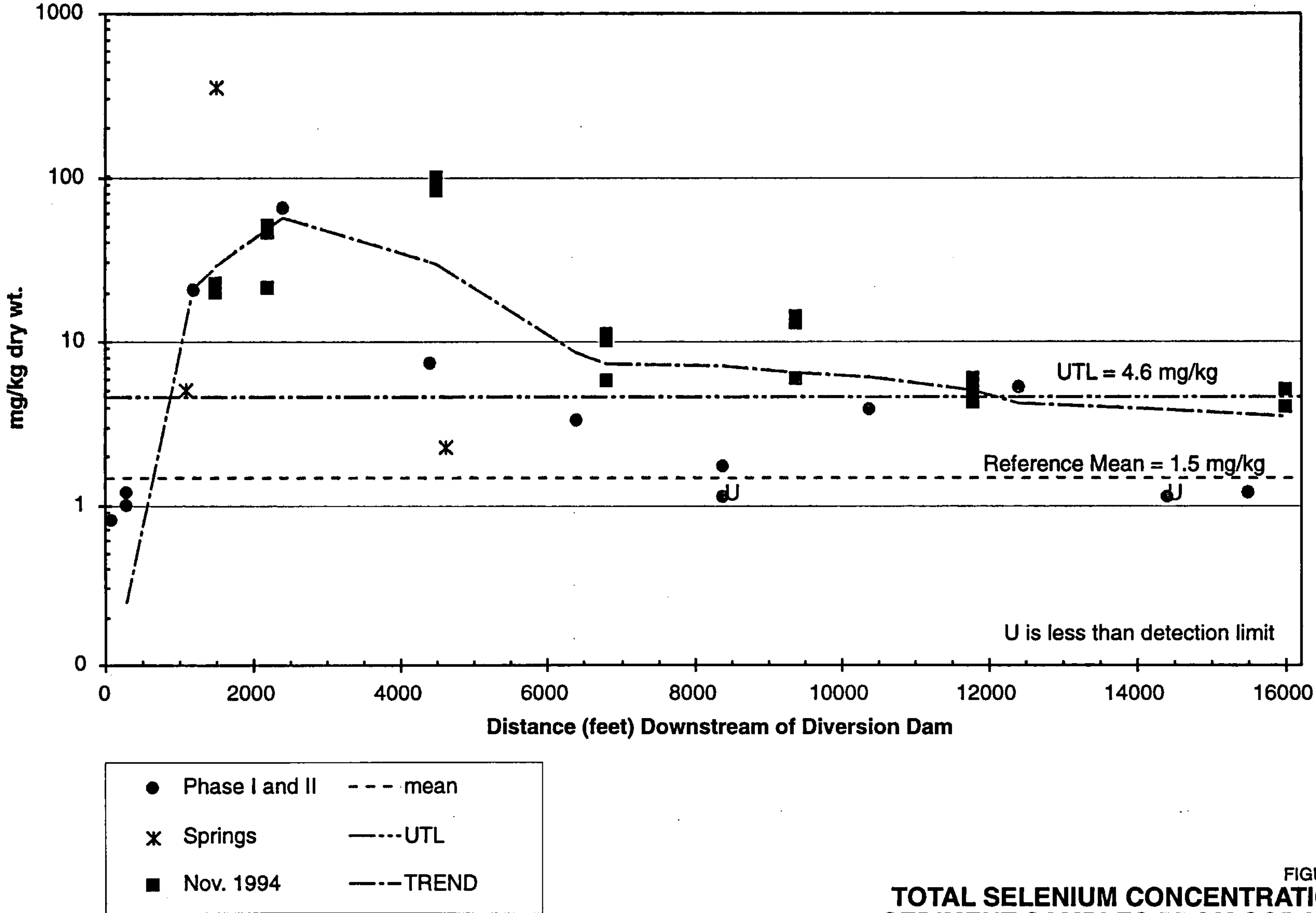


FIGURE **5-5**

TOTAL SELENIUM CONCENTRATION FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50872 DATE 5/23/95 DRAWN BY TK

Golder Associates

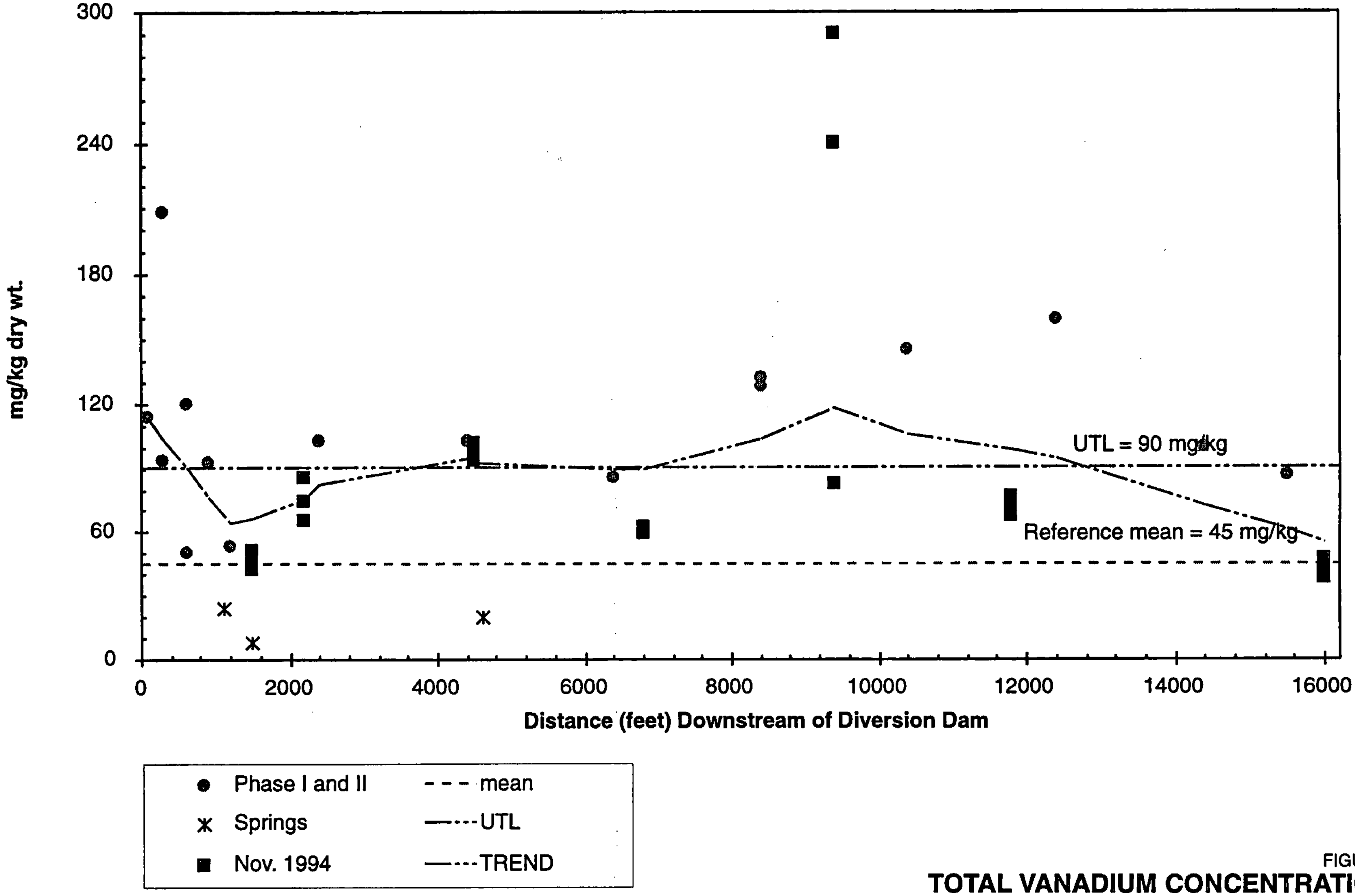


FIGURE **5-6**

TOTAL VANADIUM CONCENTRATION FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50873 DATE 5/23/95 DRAWN BY TK

Golder Associates

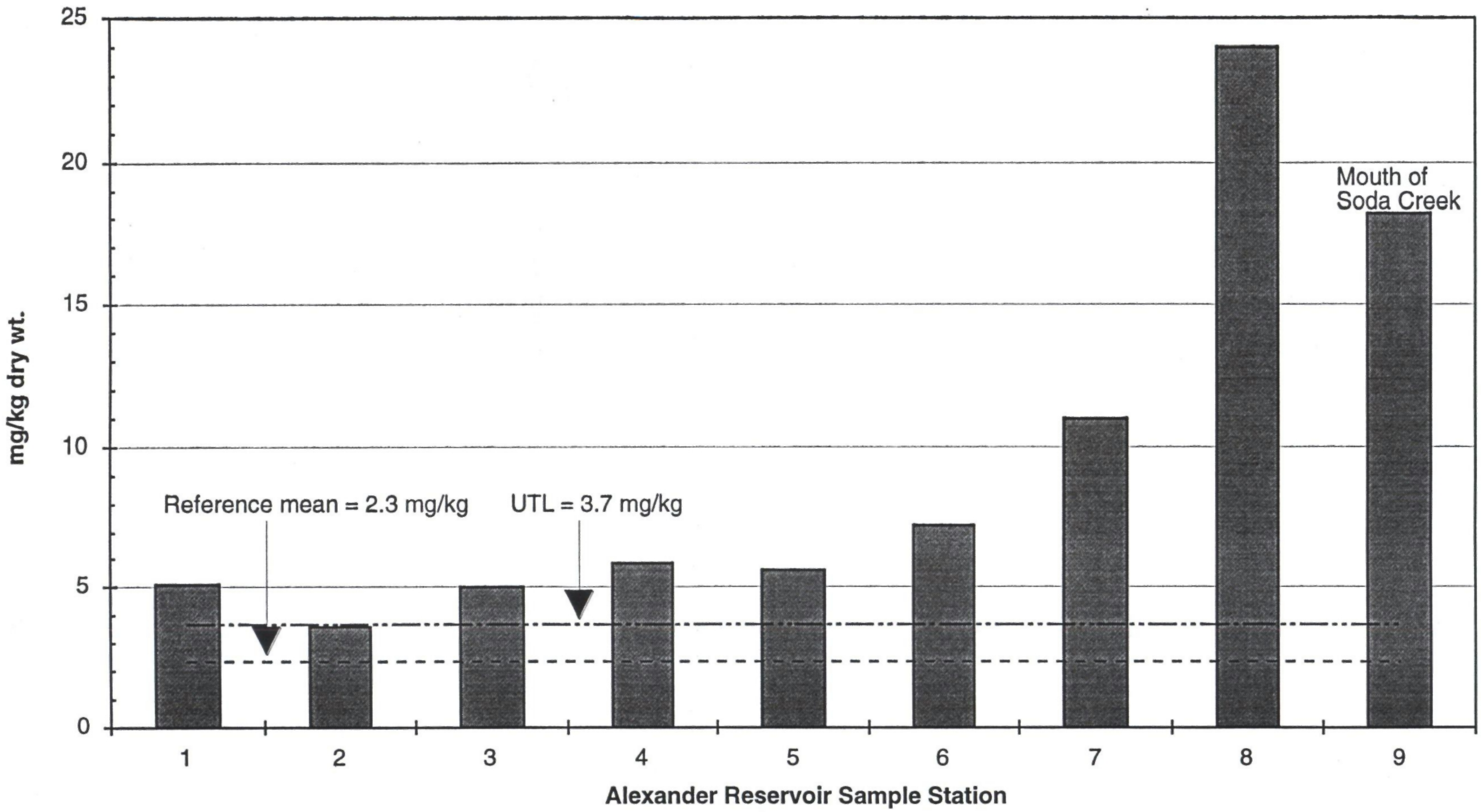


FIGURE **5-7**

TOTAL ARSENIC CONCENTRATION FOR SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50874 DATE 5/24/95 DRAWN BY TK

Golder Associates

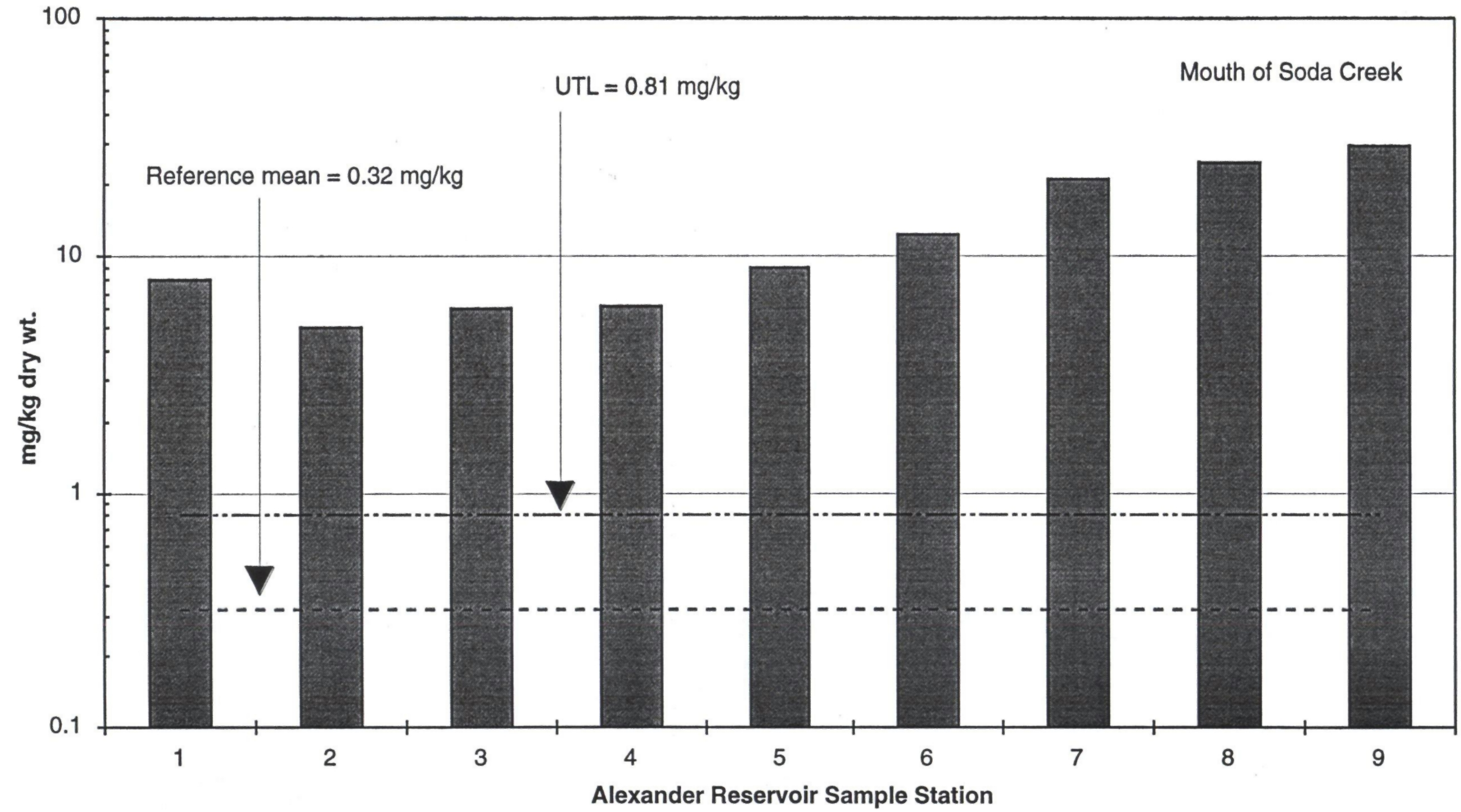


FIGURE **5-8**
TOTAL CADMIUM CONCENTRATION FOR SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR
MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50875 DATE 5/23/95 DRAWN BY TK

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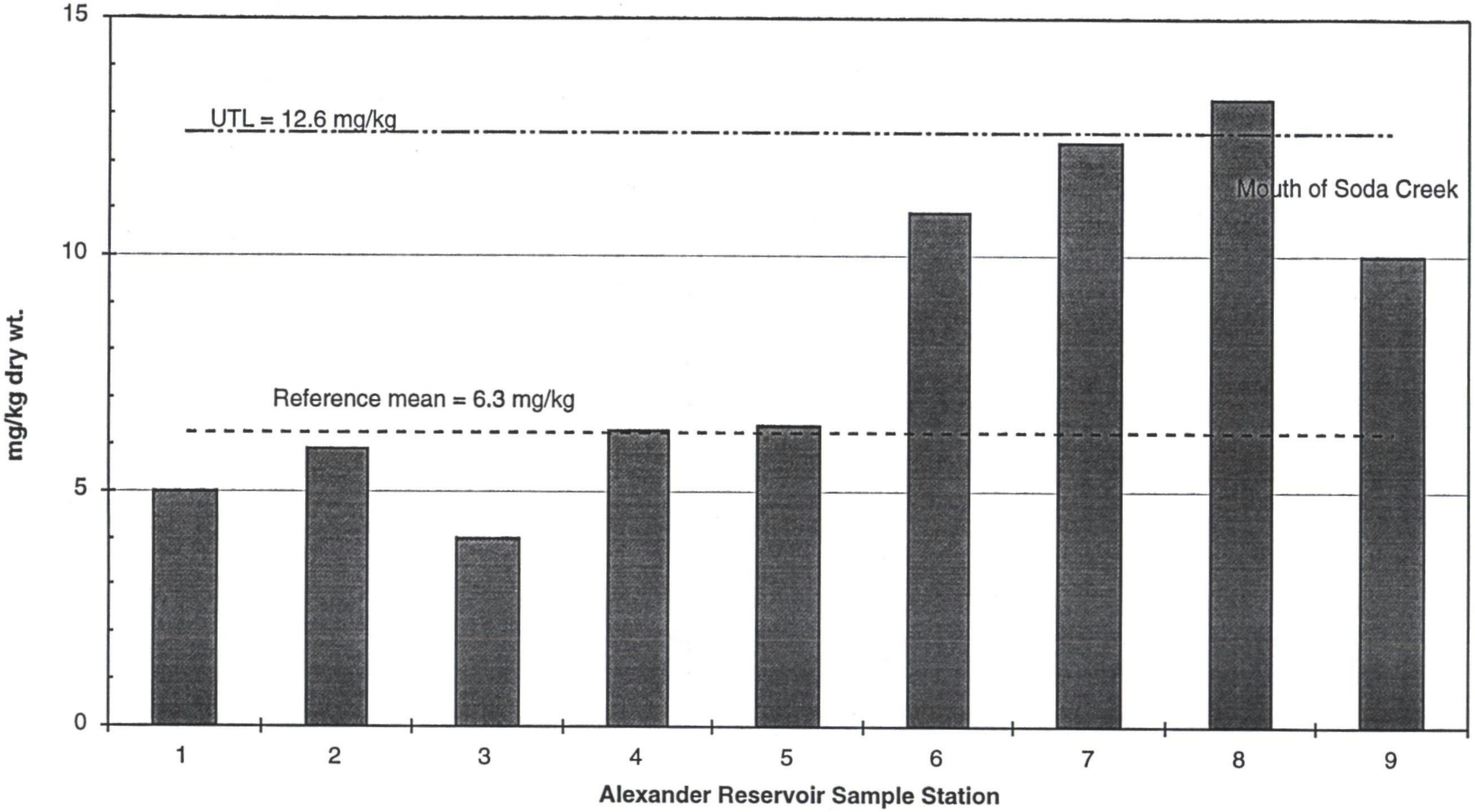

FIGURE **5-9**

TOTAL COPPER CONCENTRATION FOR SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

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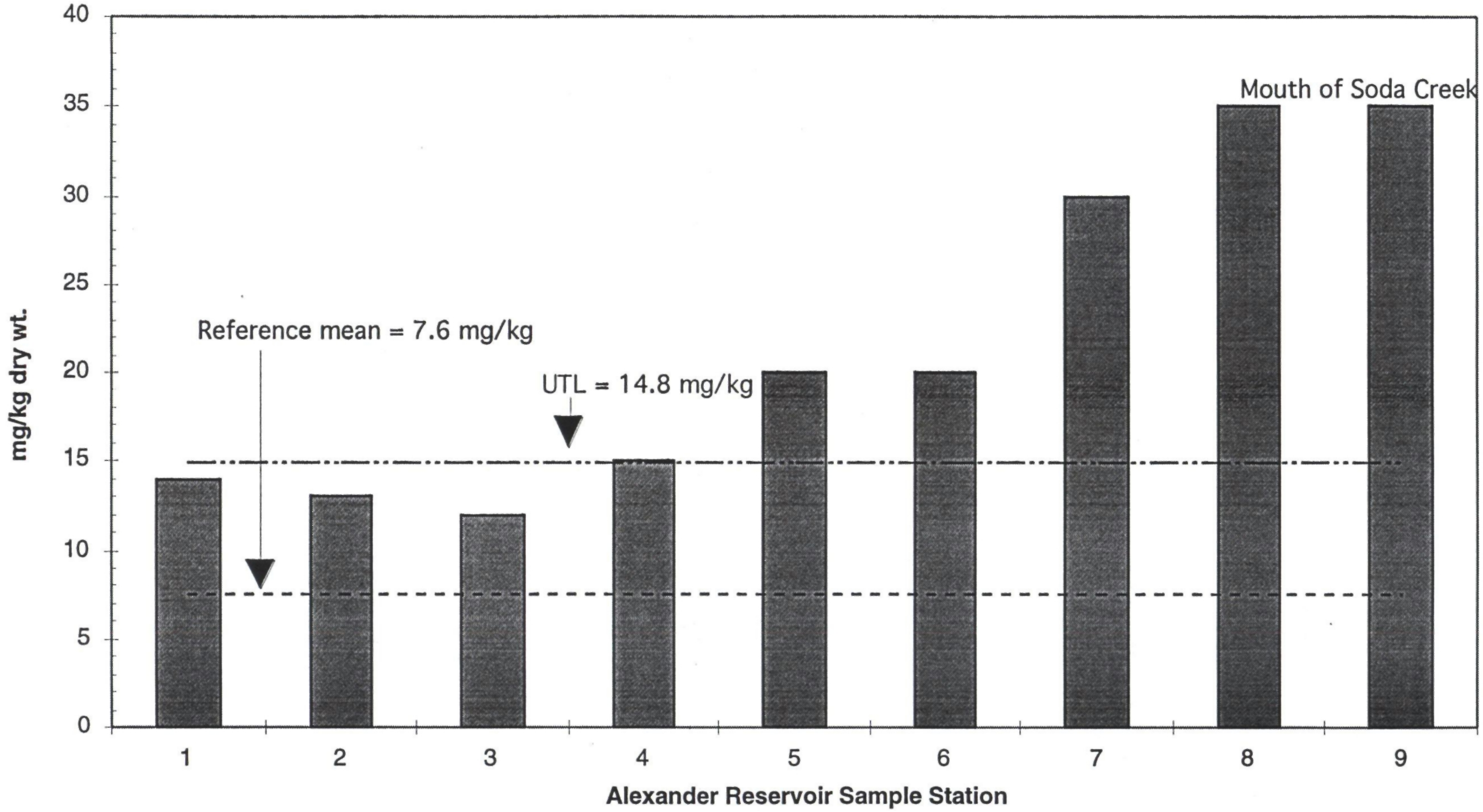

FIGURE **5-10**
TOTAL NICKEL CONCENTRATION FOR SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR
MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50877 DATE 5/24/95 DRAWN BY TK

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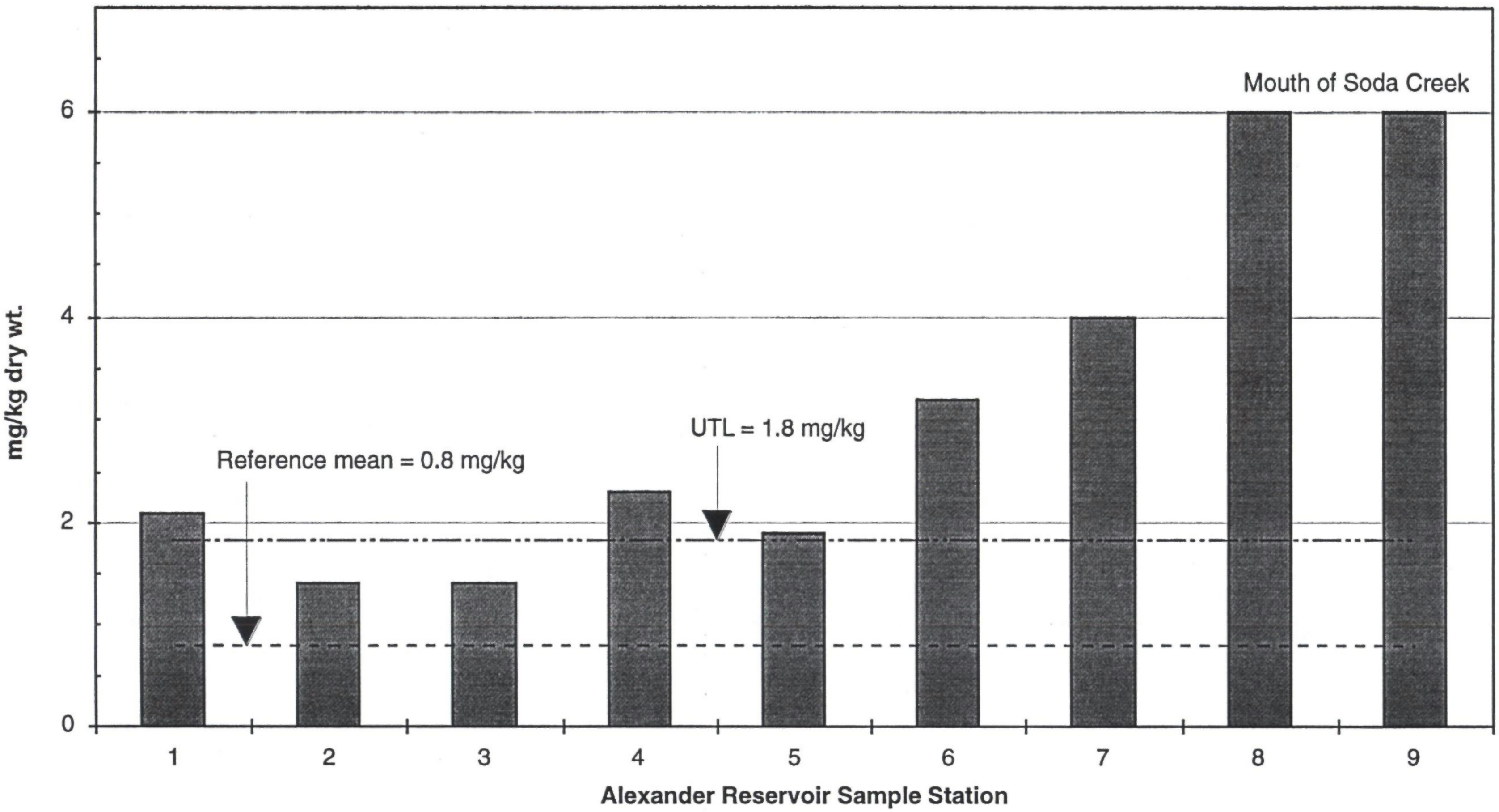

FIGURE **5-11**

TOTAL SELENIUM CONCENTRATION FOR SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

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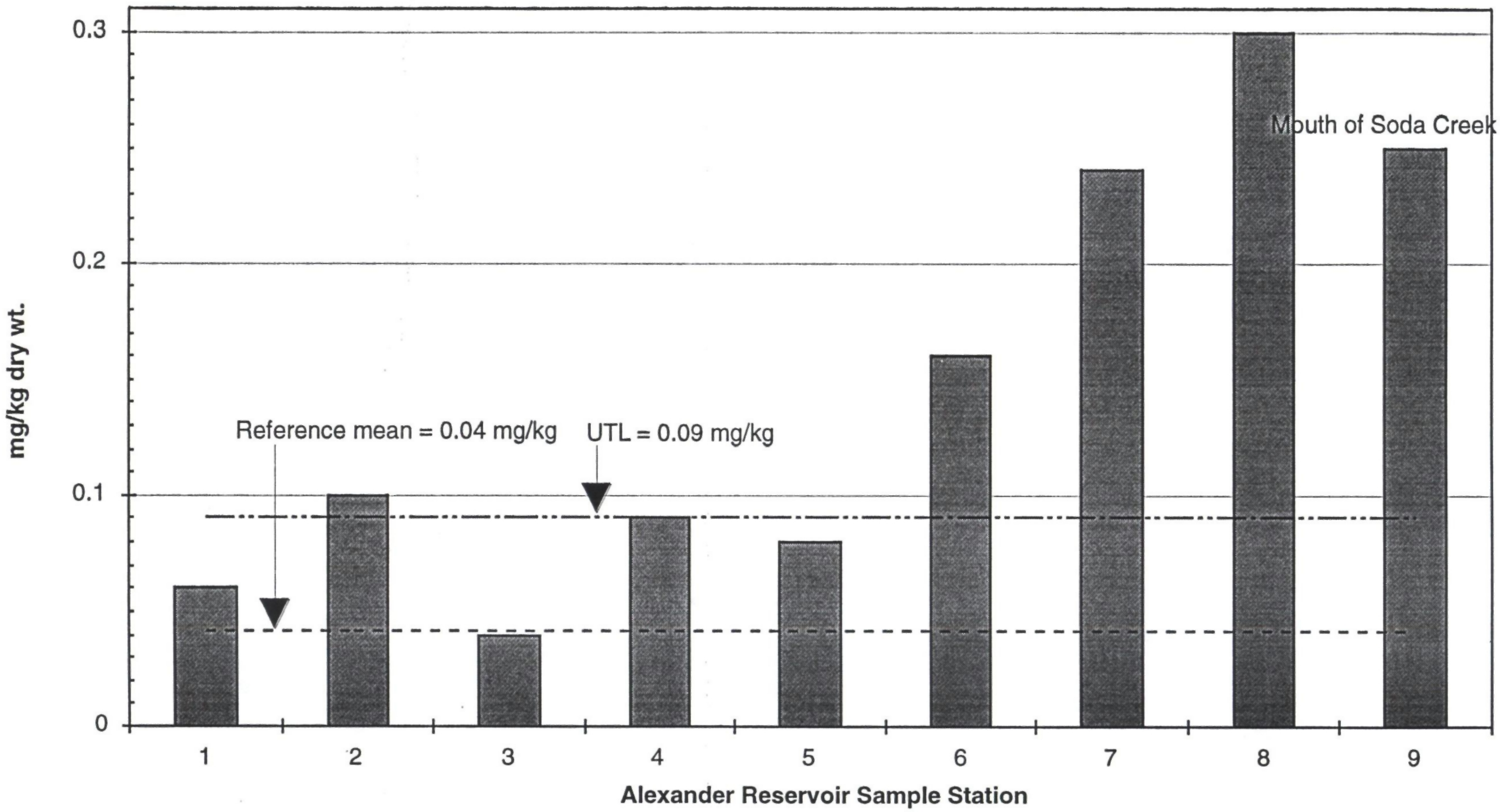

FIGURE **5-12**

TOTAL SILVER CONCENTRATION FOR SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

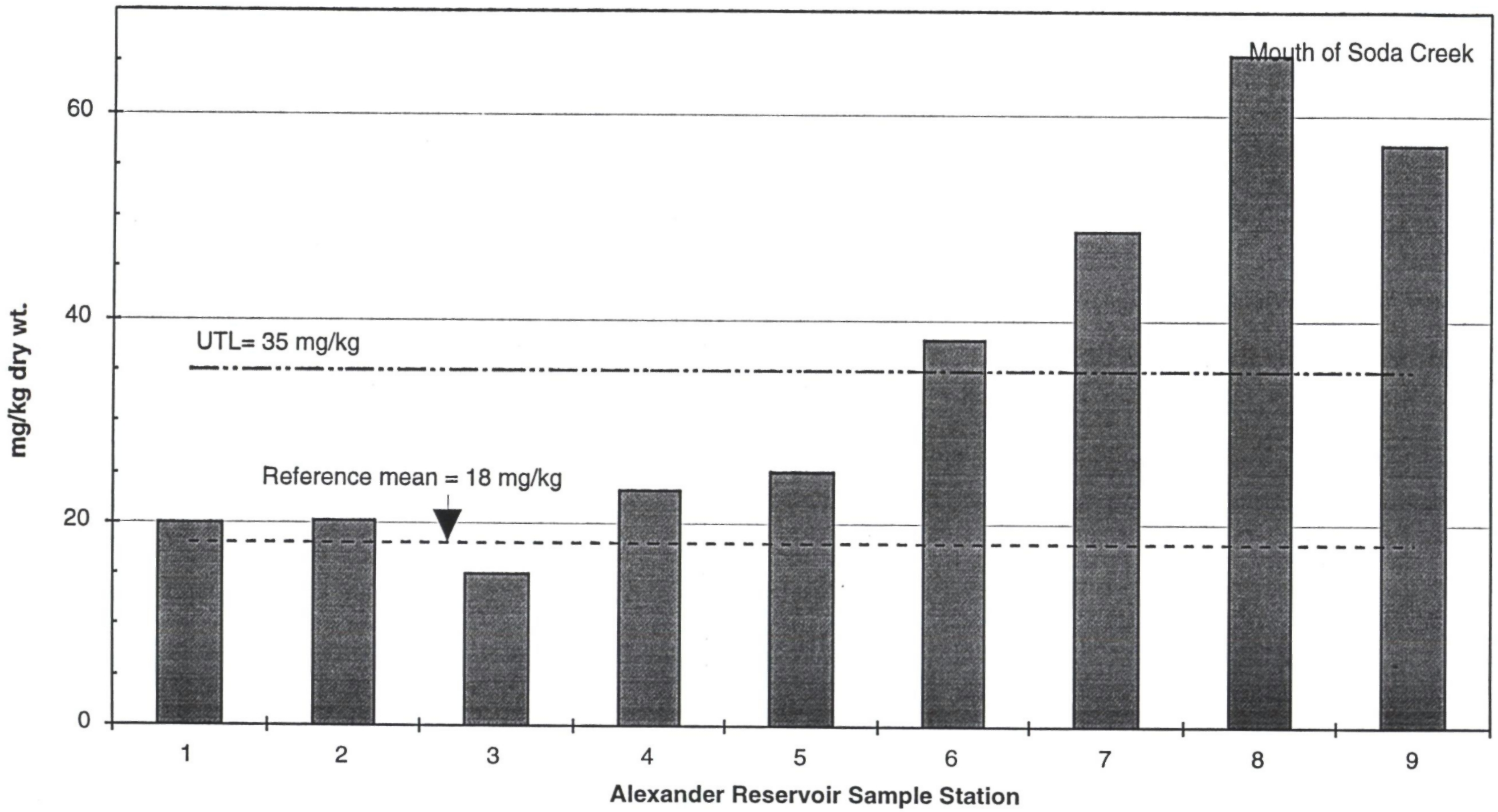

FIGURE **5-13**
TOTAL VANADIUM CONCENTRATION FOR SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR
MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

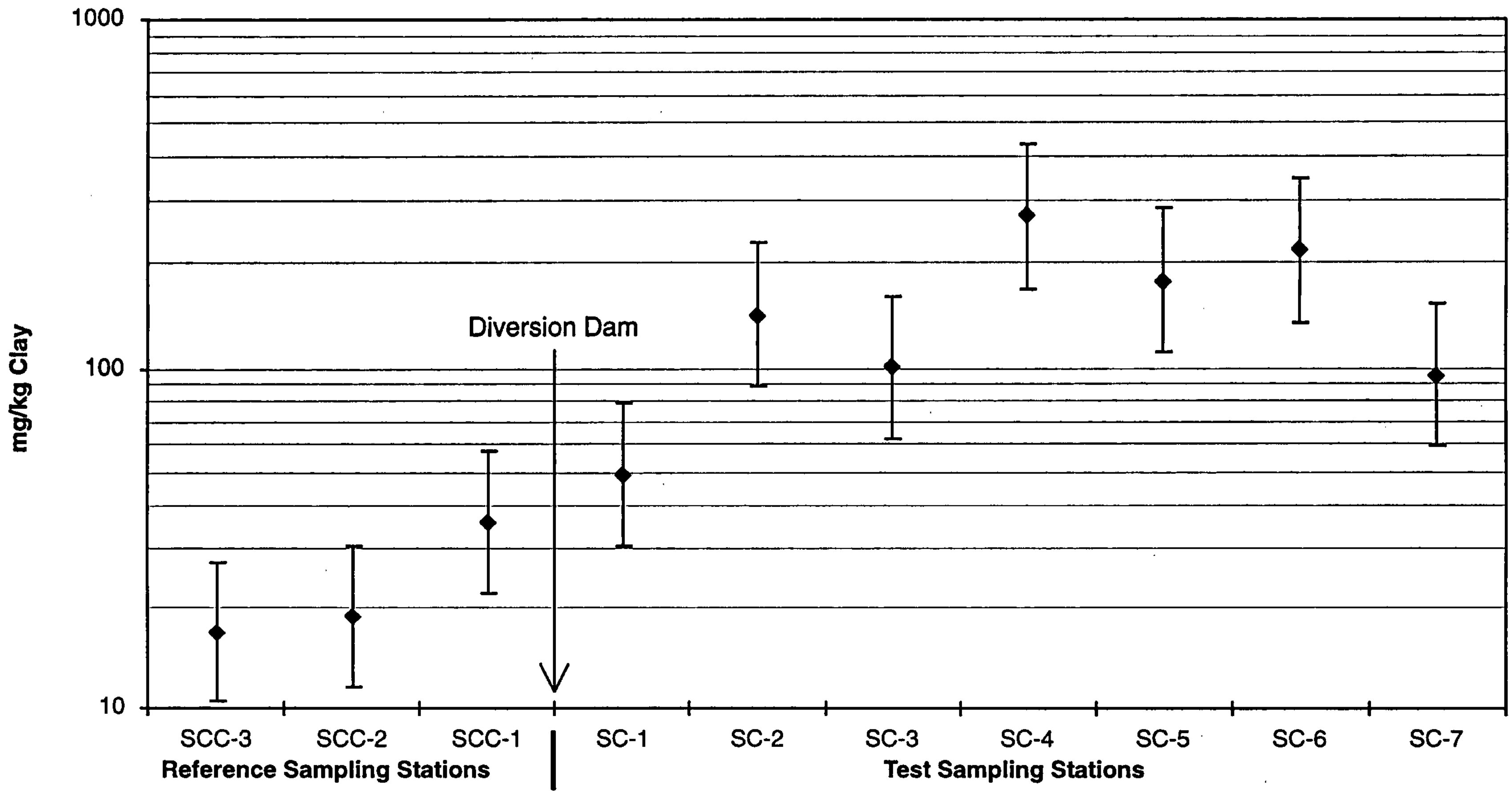

FIGURE **5-14**

STANDARDIZED MEAN ARSENIC CONCENTRATIONS AND MULTIPLE COMPARISON ERROR BARS IN SODA CREEK SEDIMENTS

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50937 DATE 5/23/95 DRAWN BY TK

Golder Associates

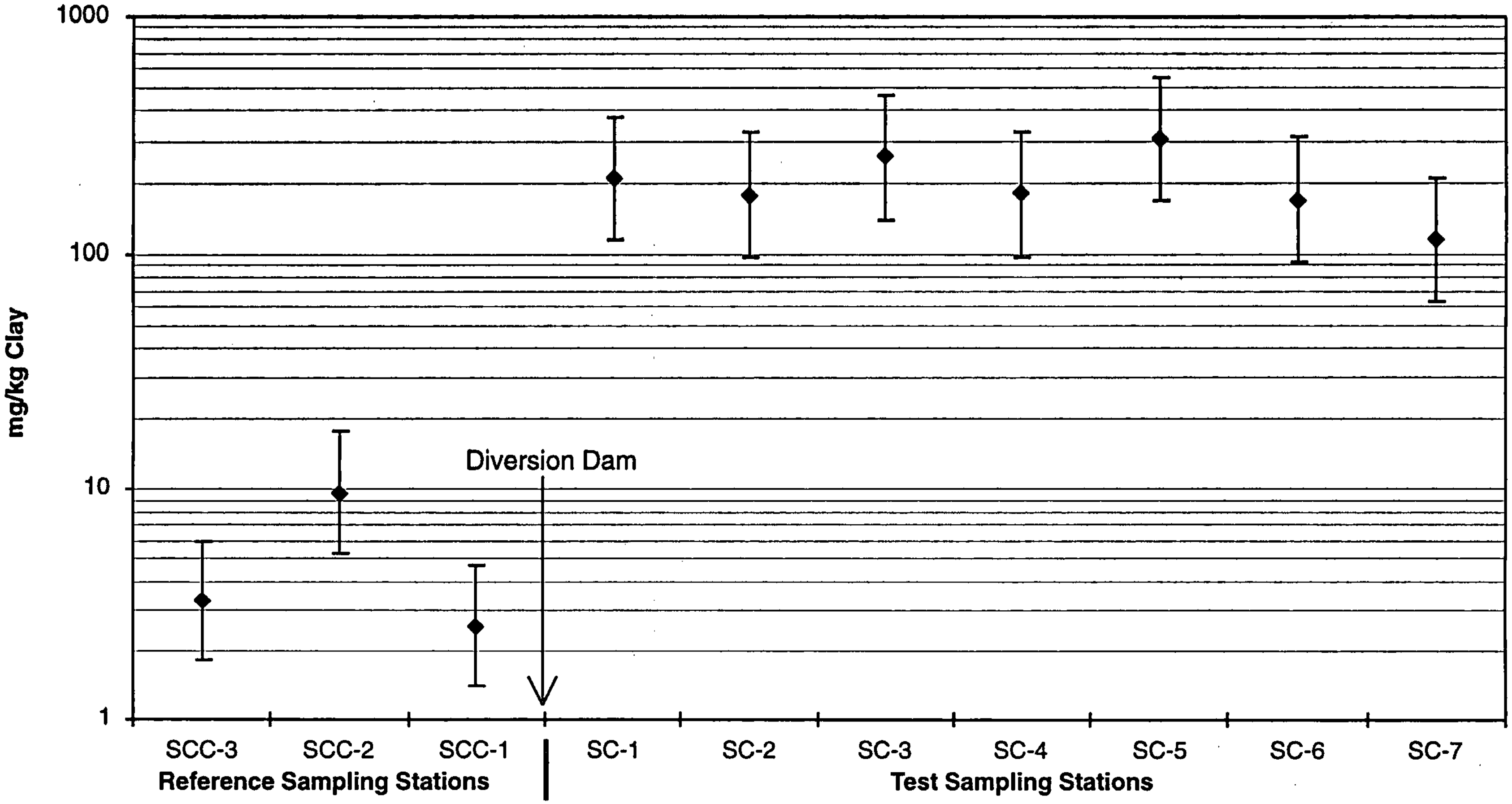

FIGURE **5-15**

STANDARDIZED MEAN CADMIUM CONCENTRATIONS AND MULTIPLE COMPARISON ERROR BARS IN SODA CREEK SEDIMENTS

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50938 DATE 5/23/95 DRAWN BY TK

Golder Associates

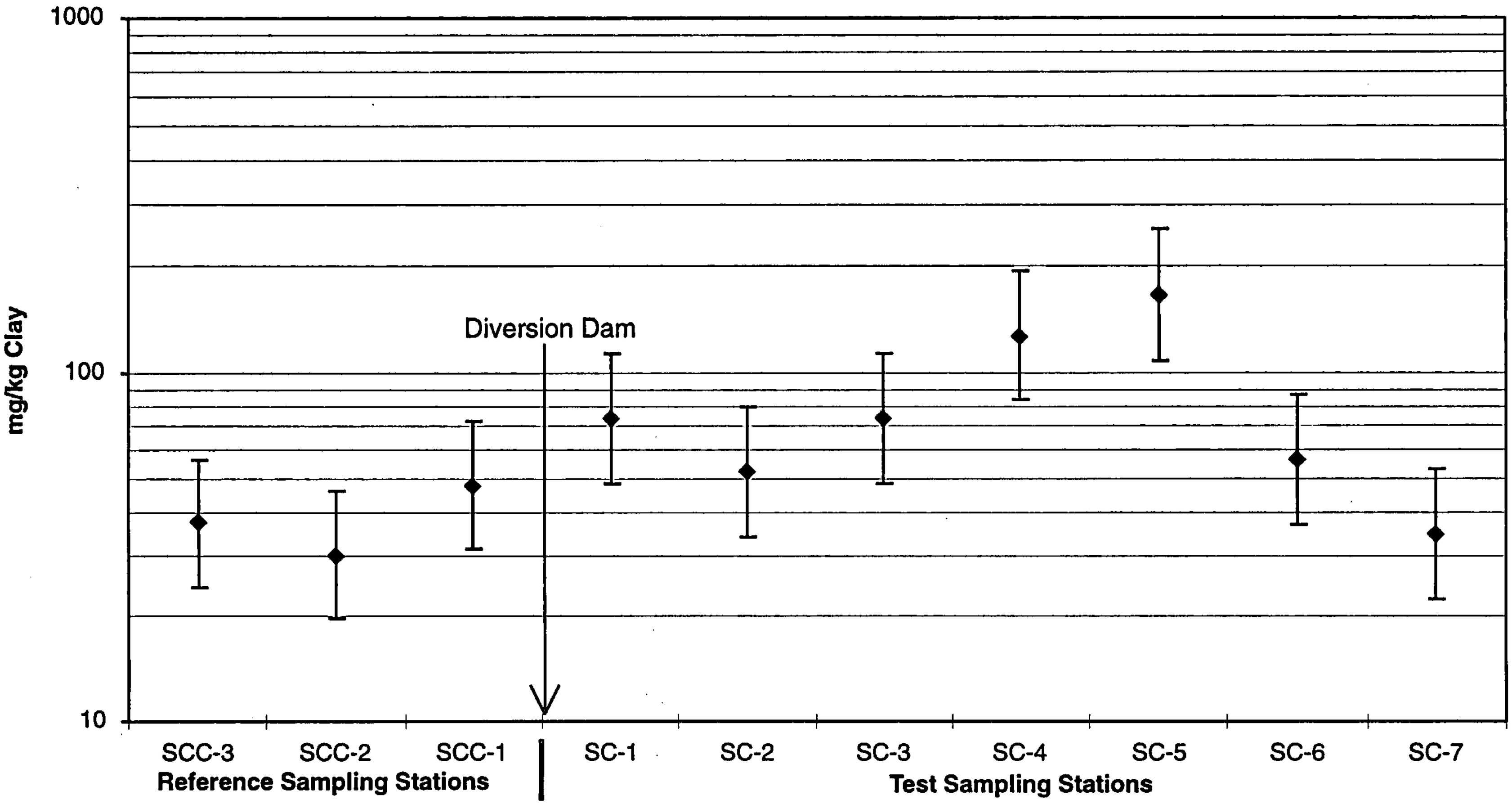

FIGURE **5-16**

STANDARDIZED MEAN COPPER CONCENTRATIONS AND MULTIPLE COMPARISON ERROR BARS IN SODA CREEK SEDIMENTS

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50939 DATE 5/23/95 DRAWN BY TK

Golder Associates

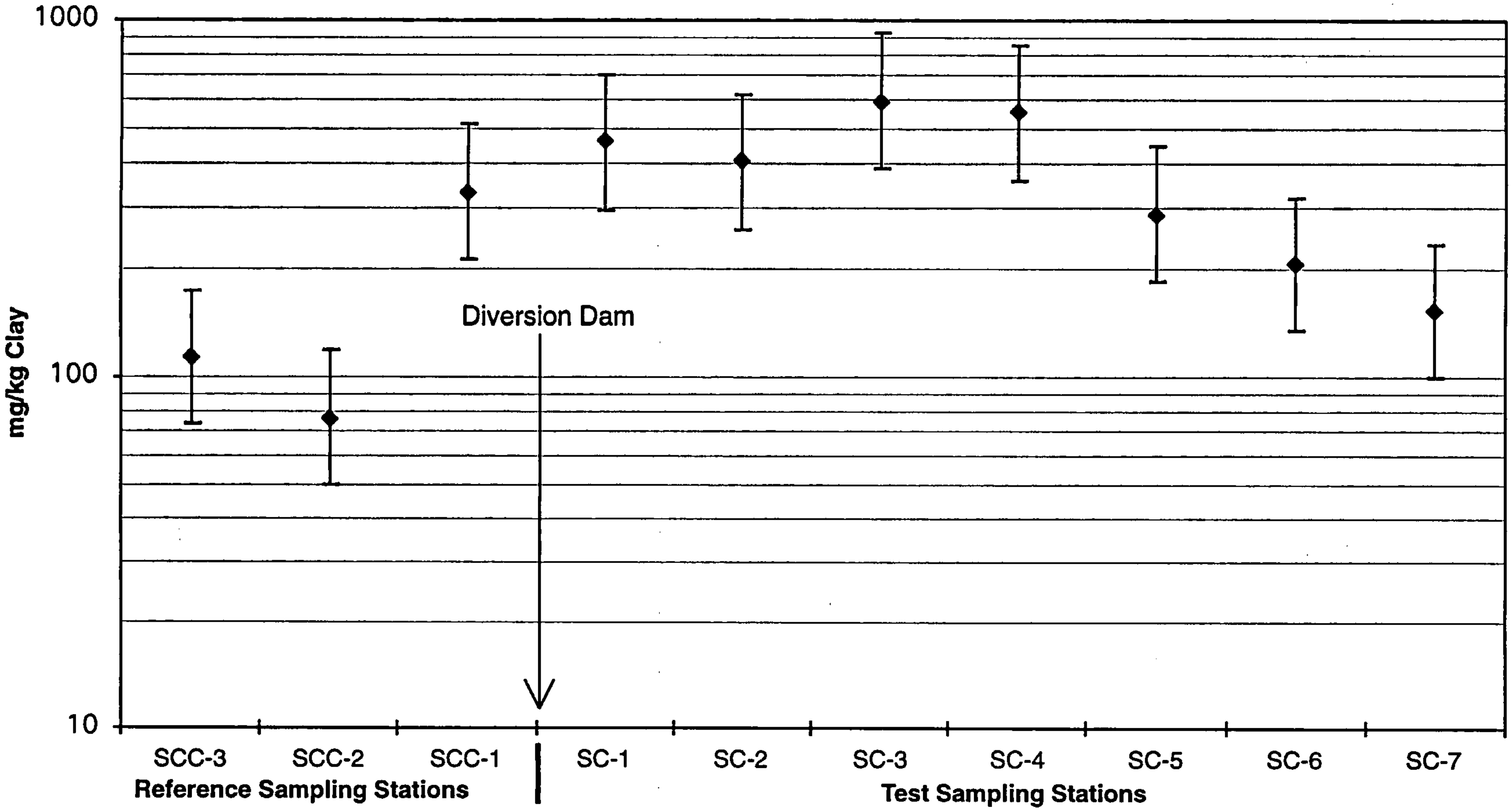

FIGURE 5-17

STANDARDIZED MEAN NICKEL CONCENTRATIONS AND MULTIPLE COMPARISON ERROR BARS IN SODA CREEK SEDIMENTS

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50940 DATE 5/23/95 DRAWN BY TK

Golder Associates

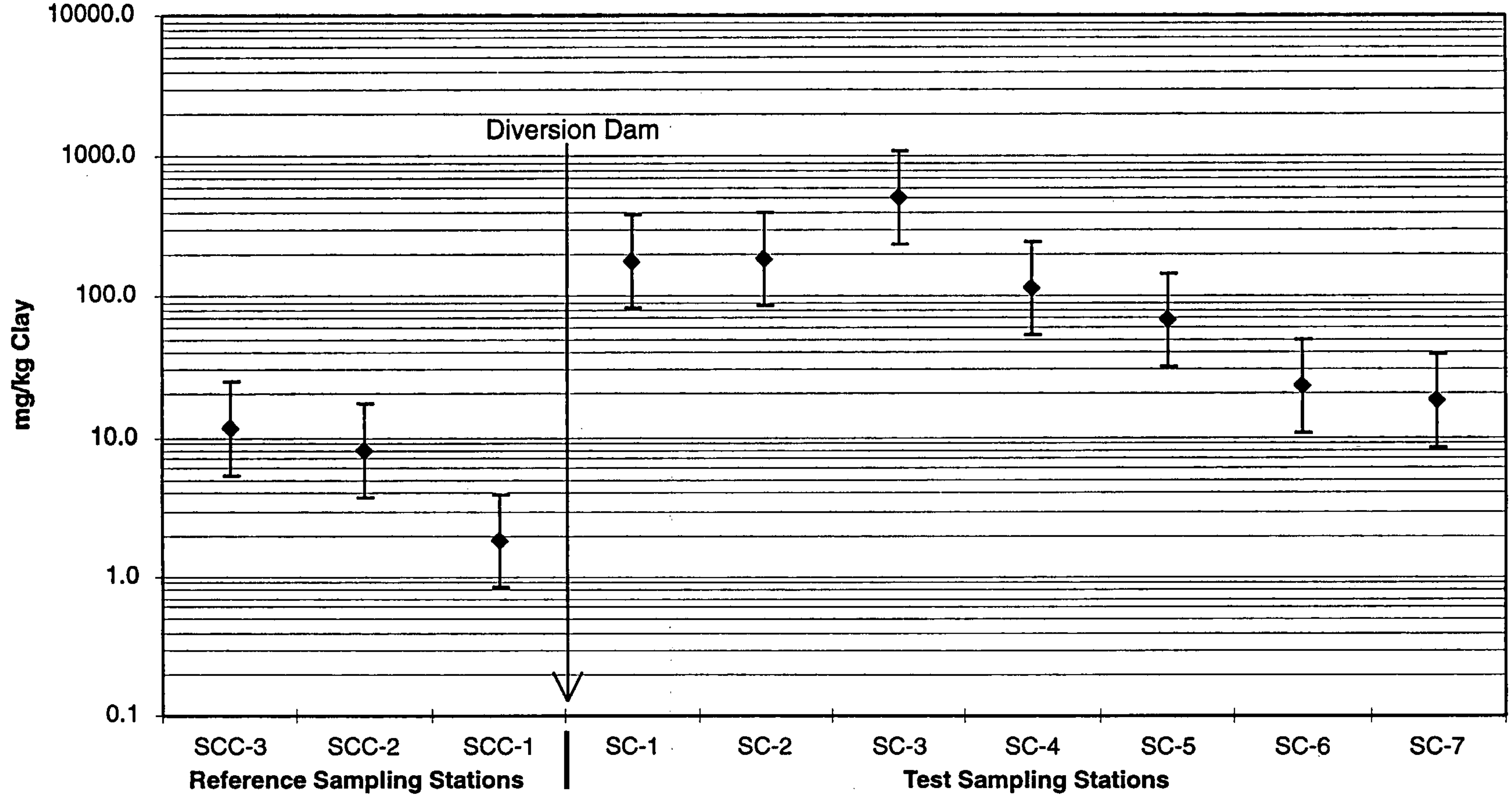

FIGURE **5-18**
STANDARDIZED MEAN SELENIUM CONCENTRATIONS AND MULTIPLE COMPARISON ERROR BARS IN SODA CREEK SEDIMENTS
MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

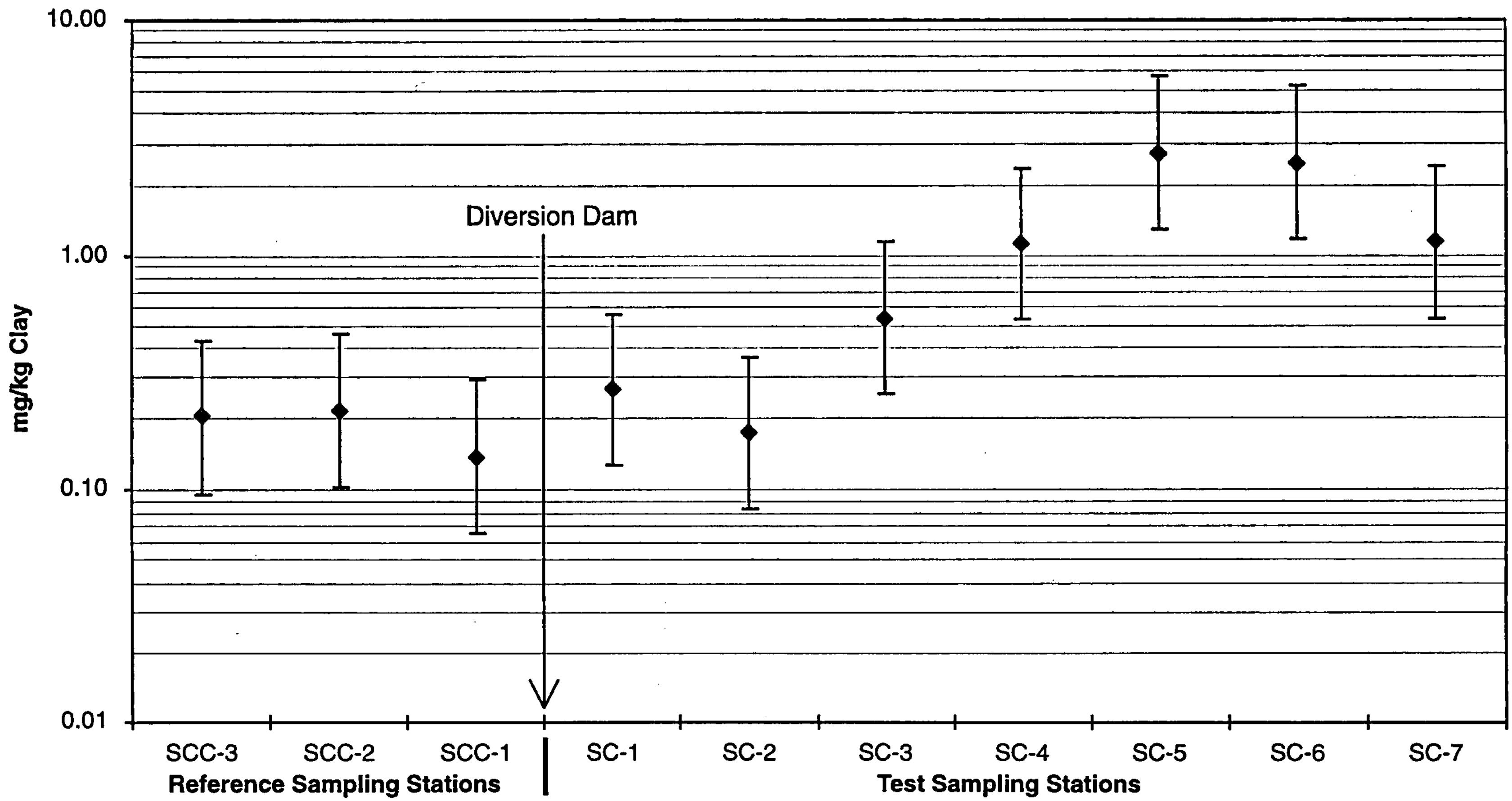

FIGURE **5-19**

STANDARDIZED MEAN SILVER CONCENTRATIONS AND MULTIPLE COMPARISON ERROR BARS IN SODA CREEK SEDIMENTS

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

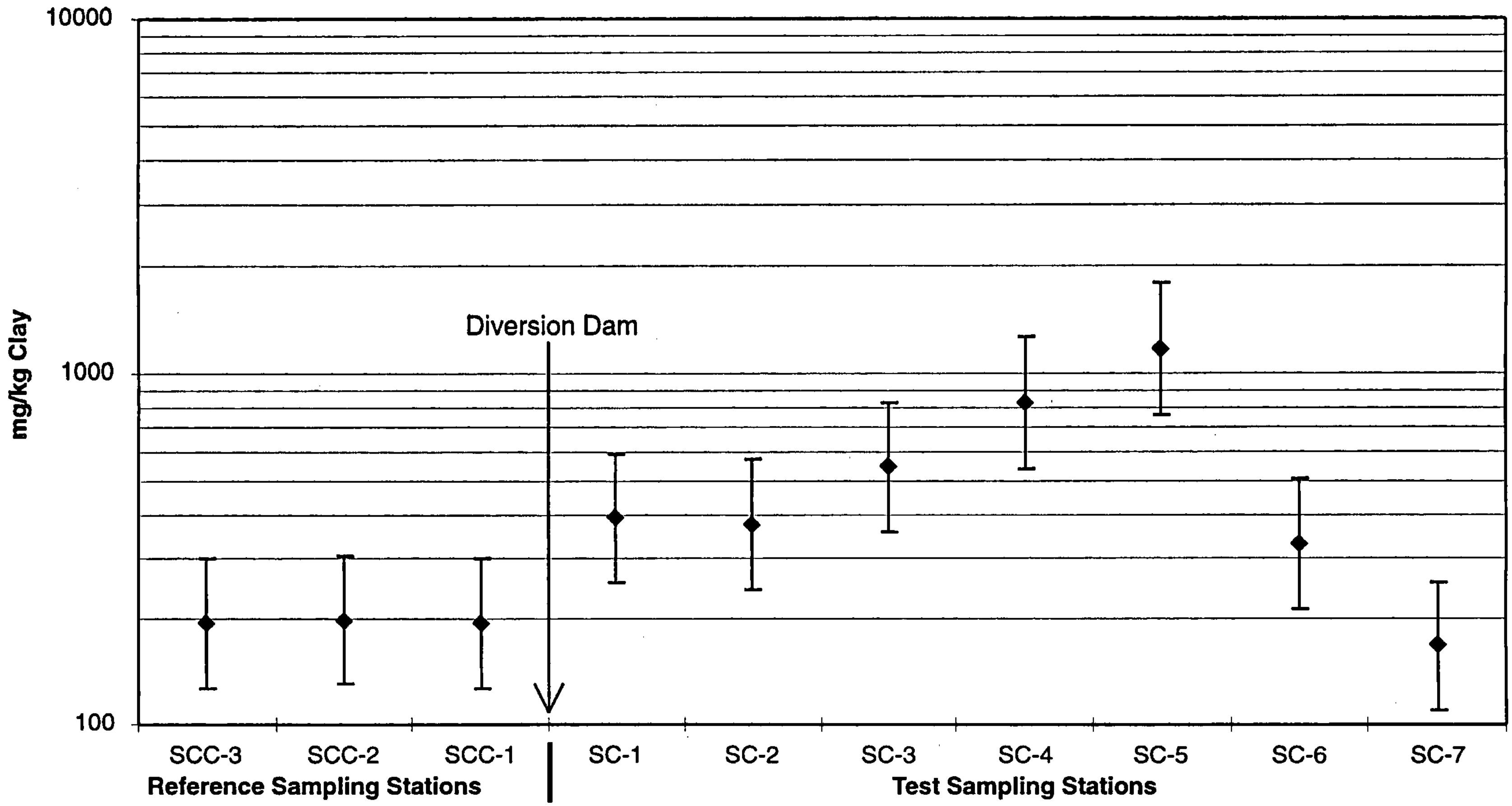

FIGURE **5-20**

STANDARDIZED MEAN VANADIUM CONCENTRATIONS AND MULTIPLE COMPARISON ERROR BARS IN SODA CREEK SEDIMENTS

MONSANTO/SODA CREEK SEDIMENT SAMPLING REPORT/ID

PROJECT NO. 913-1101.603 DRAWING NO. 50943 DATE 5/23/95 DRAWN BY TK

Golder Associates

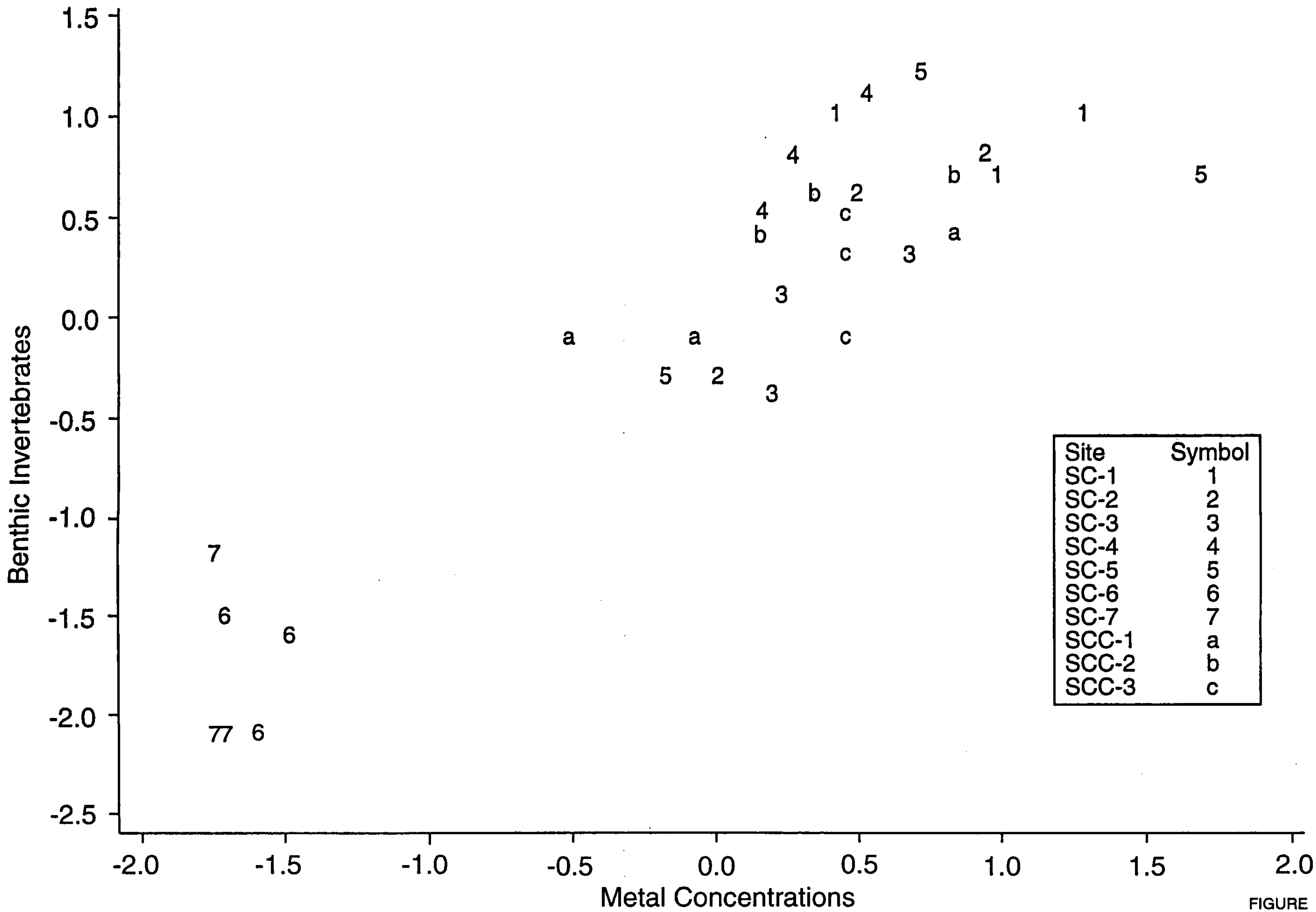

FIGURE **5-21**

FIRST SET OF CANONICAL COVARIATES FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SOIL SED/WA

PROJECT NO. 913 1101.0603 DRAWING NO. 60075 DATE 5/23/95 DRAWN BY EA

Golder Associates

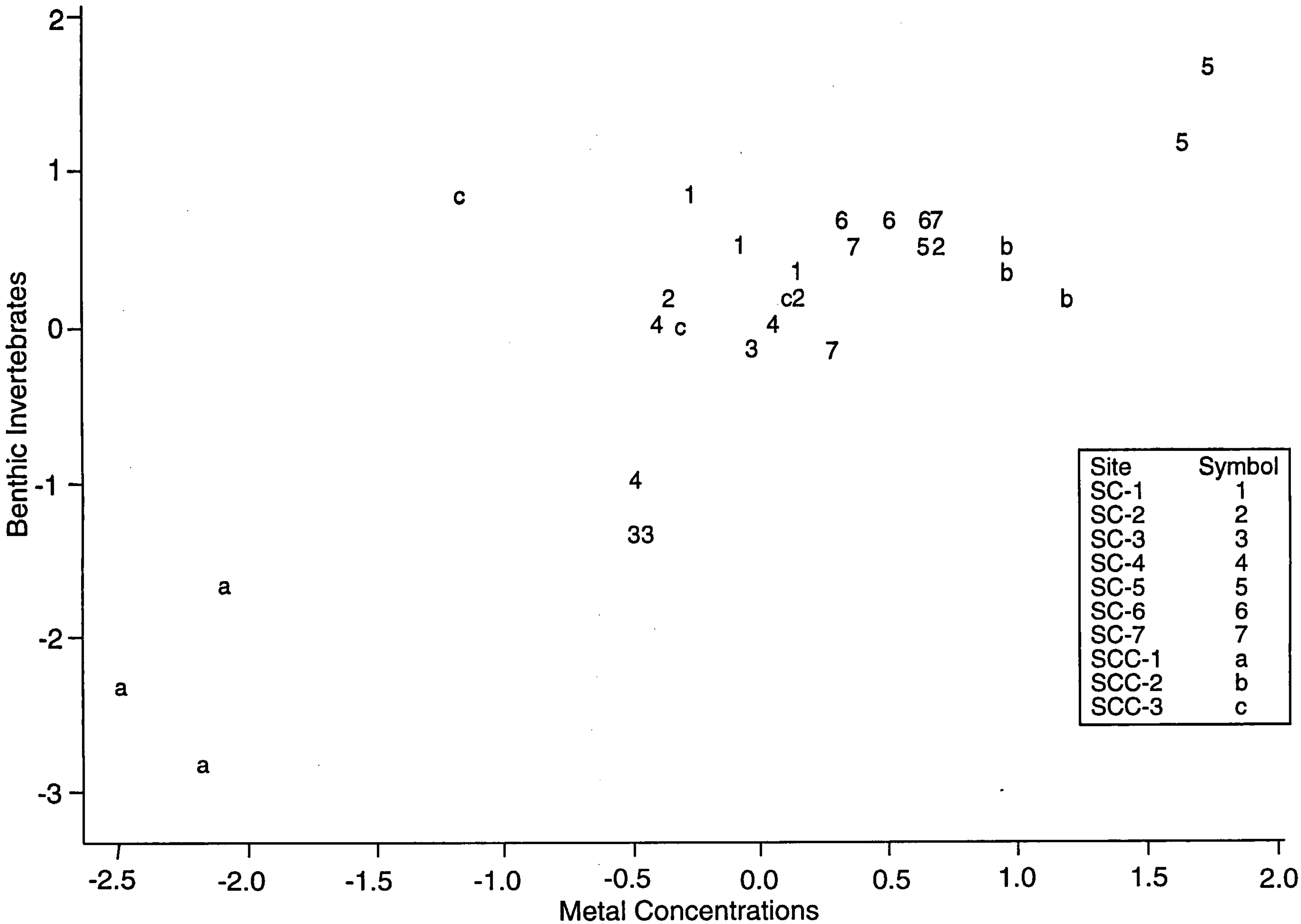

FIGURE **5-22**

SECOND SET OF CANONICAL COVARIATES FOR SEDIMENT SAMPLES FROM SODA CREEK

MONSANTO/SOIL SED/WA

PROJECT NO. 913 1101.0603 DRAWING NO. 60076 DATE 5/23/95 DRAWN BY EA

Golder Associates

Tables

TABLES

TABLE 3-1

SURFACE WATER QUALITY DATA

SAMPLE LOCATION SAMPLE DATE	EFFLUENT A (mg/L) 10/25/91	QUAL	EFFLUENT B (mg/L) 10/25/91	QUAL	EFFLUENT C (mg/L) 10/25/91	QUAL	UP NEAR (mg/L) 10/25/91	QUAL	UP MIDDLE (mg/L) 10/25/91	QUAL	UP FAR (mg/L) 10/25/91	QUAL	DOWN A (mg/L) 10/25/91	QUAL	DOWN B (mg/L) 10/25/91	QUAL	DOWN C (mg/L) 10/25/91	QUAL
Aluminum	0.08	U	0.07	U	0.1		0.09		0.11		0.07	U	0.09		0.11		0.11	
Ammonium -Nitrogen	0.1	U	0.1	U	0.1	U	0.13	U	0.37	U	0.1	U	0.12	U	0.12	U	0.43	U
Arsenic	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U	0.002	U
Beryllium	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U	0.001	U
Cadmium	0.01		0.009		0.011		0.005	U	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
Calcium	130		138		128		84.6		79.8		77.6		88.4		83.7		86.2	
Chloride	159		149		153		15		15		13		29		30		25	
Chromium	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U
Copper	0.007	U	0.008	U	0.008	U	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U	0.005	U
Fluoride	0.43		0.42		0.4		0.31		0.31		0.31		0.31		0.34		0.34	
Iron	0.051	U	0.046	U	0.04	U	0.93		0.47	U	0.43	U	0.54	U	0.54	U	0.59	U
Lab pH	8	J	8	J	8	J	6.8	J	7.1	J	7.1	J	7.1	J	7	J	7	J
Lead	0.001	UJ	0.001	UJ	0.001	UJ	0.001	UJ	0.001	UJ	0.001	UJ	0.001	UJ	0.001	UJ	0.002	UJ
Magnesium	61.4		65		60.3		84.1		78.4		75.5		76.5		75		78.7	
Manganese	0.005	U	0.005	U	0.005	U	0.083		0.062		0.058		0.06		0.063		0.063	
Nickel	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U	0.02	U
Nitrate-Nitrogen	4.7		4.8		4.55		0.65		0.74		0.73		1.16		1.14		1.14	
Ortho-Phosphate	1.06		1.06		1.08		0.13	U	0.13	U	0.1	U	0.21	U	0.24	U	0.22	U
Potassium	7.3		7.8		7.3		10.4		9.9		9.3		9.3		9.6		10	
Selenium	.03*		.02*		.02*													
Silver	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U	0.01	U
Sodium	105		113		104		22		21.2		20.7		31.2		29.9		31.1	
Sulfate	96		96		96		36		30		36		42		42		42	
Vanadium	0.12	U	0.12	U	0.21		0.01	U	0.01	U	0.01	U	0.03	U	0.03	U	0.03	U
Zinc	0.025	U	0.037	U	0.031	U	0.014	U	0.01	U	0.009	U	0.012	U	0.015	U	0.008	U
*SAMPLE DATE IS 6/9/93																		

NOTE: See Figure 3-1 for Sample Locations

TABLE 3-2

WATER QUALITY OF MORMON SPRINGS

Constituent	Units	Oct-91	May-92	Nov-92	May-93	Oct-93	Apr-94	Nov-94	Mean	Standard Deviation
Aluminum	mg/L	0.05	0.065	0.0565	0.0228	0.0245	0.0949	0.01	0.046	0.0294
Ammonia (as N)	mg/L	0.05	0.025	0.015	0.015	0.015	0.015	0.023	0.023	0.0128
Arsenic	mg/L	0.002	0.002	0.001	0.0005	0.0009	0.002	0.025	0.0048	0.00894
Beryllium	mg/L	0.001 U	0.005 U	0.0008 U	NM	NM	NM	NM	<0.005	
Cadmium	mg/L	0.018	0.01	0.0148	0.0153	0.0127	0.0161	0.0021	0.013	0.00533
Calcium	mg/L	116	121	111	NM	NM	NM	NM	116	5.00
Chloride	mg/L	113	143	120	143	178	142	130	138	21.1
Chromium	mg/L	0.01 U	0.01 U	NM	NM	NM	NM	NM	<0.01	
Copper	mg/L	0.005 U	0.013 U	NM	NM	NM	NM	NM	<0.013	
Fluoride	mg/L	2.2	2.96	2.2	3.6	3.6	3.78	2.9	3.0	0.660
Iron	mg/L	0.0125	0.0125	0.007	0.053	0.123	0.0175	0.0025	0.033	0.0432
Lead	mg/L	0.001 U	0.005 U	NM	NM	NM	NM	NM	<0.005	
Magnesium	mg/L	73	67	67.2	NM	NM	NM	NM	69	3.41
Manganese	mg/L	0.0025	0.0025	0.0012	0.0118	0.0123	0.0015	0.0005	0.0046	0.00513
Molybdenum	mg/L	NM	0.05	0.0514	0.0763	0.0806	0.0923	0.067	0.070	0.0168
Nickel	mg/L	0.02	0.015	0.0144	0.013	0.0108	0.0227	0.02	0.017	0.00436
Nitrate-Nitrite (as N)	mg/L	2.8	3.89	2.9	5.76	5.04	6.53	4.4	4.5	1.40
pH		7.2	7.3	7.26	7.52	7.26	7.08	7.2	7.26	0.135
Potassium	mg/L	14.6	10	10.4	NM	NM	NM	NM	12	2.55
Selenium	mg/L	0.0015	0.17	0.124	0.186	0.1676	0.168	0.14	0.14	0.0631
Silver	mg/L	0.01 U	0.0002 U	NM	NM	NM	NM	NM	<0.01	
Sodium	mg/L	70.2	62	69.5	NM	NM	NM	NM	67	4.55
Sulfate	mg/L	114	170	159	268	267	305	190	210	70.1
Vanadium	mg/L	0.01	0.01	0.0126	0.0205	0.01765	0.0258	0.017	0.016	0.00582
Zinc	mg/L	0.151	0.195	0.133	0.208	0.22	0.266	0.175	0.19	0.0447

NOTE: Shaded values indicate constituent not detected, value shown is one-half the detection limit.
U = Undetected
NM = Not measured

TABLE 3-3

METAL LOADING TO SODA CREEK AT THE MONSANTO OUTFALL AND MORMON SPRINGS

Site	Arsenic		Cadmium		Copper		Molybdenum		Nickel		Selenium		Silver		Vanadium	
	mg/L	kg/day	mg/L	kg/day	mg/L	kg/day	mg/L	kg/day	mg/L	kg/day	mg/L	kg/day	mg/L	kg/day	mg/L	kg/day
Outfall*	NC	NC	0.01	0.110	NC	NC	NM	-	NC	NC	0.023	0.25	NC	NC	0.11	1.200
Mormon Springs**	0.0048	0.0013	0.013	0.0035	NC	NC	0.07	0.019	0.017	0.0046	0.14	0.038	NC	NC	0.016	0.0044

* = Assumed flow is 2020 gallons/minute
** = Assumed flow is 50 gallons/minute
NM = Not Measured
N/C = Not Calculated. Concentration less than detection level.

TABLE 3-4

CONSTITUENT SUMMARY OF PHASE I SODA CREEK SEDIMENT SAMPLES

Constituent	Units	Reference Sample			Downstream Sediments	
		Mean (n=3)	Standard Deviation	Maximum Detected	Maximum Detected Concentrations	Number of Samples Exceeding Maximum Reference
Aluminum	(mg/kg)	6,477	2,842	8,780	8,460	0
Arsenic	(mg/kg)	6.2	2.12	8.6	15	2
Beryllium	(mg/kg)	3.2	1.04	4	3	0
Cadmium	(mg/kg)	11	2.81	13.9	61	3
Chromium	(mg/kg)	7.3	2.9	9.5	19	3
Copper	(mg/kg)	2.7	2.1	5	22	3
Fluoride	(mg/kg)	3.5	1.4	4.9	2.3	0
Iron	(mg/kg)	109,267	13,115	122,000	197,000	3
Lead	(mg/kg)	5.6	3.3	7.5	11	3
Lead-210	(pCi/g)	0.40	0.40	0.8	1.8	1
Manganese	(mg/kg)	815	297	1,050	1,270	2
Nickel	(mg/kg)	55	5.8	62	153	3
pH	(std. unit)	7.4	0.26	7.6	7.9	1
Polonium-210	(pCi/g)	0.67	0.21	0.9	3.3	1
Potassium	(mg/kg)	10433	3,371	14,200	13,900	0
Potassium-40	(pCi/g)	4.7	1.9	6.9	8.3	1
Radium-226	(pCi/g)	0.60	0.20	0.8	0.8	0
Radium-228	(pCi/g)	0.63	0.35	1.0	2.3	1
Selenium	(mg/kg)			<0.6	1.2	3
Silver	(mg/kg)			<0.1	0.5	3
Sodium	(mg/kg)	600	265	900	800	0
Thorium-228	(pCi/g)	0.50	0.10	0.6	0.5	0
Thorium-230	(pCi/g)	0.57	0.21	0.8	1.4	2
Thorium-232	(pCi/g)	0.23	0.06	0.3	0.4	1
Uranium	(pCi/g)	0.17	0.29	0.5	0.6	2
Vanadium	(mg/kg)	23	6.5	30	208	3
Zinc	(mg/kg)	26	20	47	170	3

Notes: < = Detection Level

TABLE 3-5

CONSTITUENT SUMMARY OF PHASE II SODA CREEK SEDIMENT SAMPLES

Constituent	Units	Reference Sediments			Downstream Sediments	
		Mean	Standard Deviation	Maximum Detected	Maximum Detected	Number of Exceedances
Arsenic	(mg/kg)	6.2	212	8.6	87.8	14
Cadmium	(mg/kg)	10.8	2.55	13.4	61	15
Copper	(mg/kg)	2.50	2.29	5	95.4	18
Iron	(mg/kg)	3,967	4,861	9,580	1,970	0
Molybdenum	(mg/kg)	6.5*		6.5	5	0
Nickel	(mg/kg)	55	5.77	62	153	5
Potassium	(mg/kg)	6,173	4,203	9,400	1,390	0
Selenium	(mg/kg)	0.38	0.15	0.6	347	19
Silver	(mg/kg)	<0.10	NM	<0.1	1.8	9
Vanadium	(mg/kg)	23	6.51	30	208	16
Polonium-210	(pCi/g)	0.67	0.21	0.9	3.3	5

Notes:
* = Only one sample analyzed
< = detection limit

TABLE 3-6

RESULTS OF PHASE II SODA CREEK SEDIMENT BIOLOGICAL TOXICITY TEST

Sample	Bacteria Enzyme Activity NOEC (%)	Algal Growth Reduction % of Control
Upstream		
Control A	12.5	3
Control B	25	42
Control C	25	44
Mean	*21*	*30*
Downstream		
100 A	25	5
100 B	12.5	9
100 C	6.25	2
Mean	*15*	*5*
2400 A	6.25	10
2400 B	<6.25	15
2400 C	12.5	20
Mean	*7.3*	*15*

Notes:
NOEC = No observed effects concentration
Algal growth reduction reported at sample strength of 100%.

TABLE 5-1

PHYSICAL AND CHEMICAL CHARACTERISTICS OF SEDIMENTS FROM SODA CREEK AND ALEXANDER RESERVOIR

Station	pH	TOC (%)	Sand (%)	Silt (%)	Clay (%)
Soda Creek[a]					
SCC-3	6.8± 0.057	7.3 ± 2.1	22 ± 13	58 ± 8.8	20 ± 6.9
SCC-2	6.86 ± 0.057	5.8 ± 0.86	10 ± 10.0	63 ± 7.5	27 ± 2.5
SCC-1	7.26 ± 0.305	3.3 ± 0.76	25 ± 4.6	51 ± 4.9	24 ± 1.7
SC-1	6.8 ± 0.0	6.1 ± 0.98	57 ± 3.4	33 ± 2.1	9.8 ± 1.5
SC-2	6.4 ± 0.057	6.0 ± 1.5	36 ± 7.2	48 ± 3.8	16 ± 3.7
SC-3	6.9 ± 0.15	9.1 ± 0.23	13 ± 2.5	73 ± 6.0	15 ± 3.7
SC-4	6.7 ± 0.12	2.4 ± 0.50	54 ± 10	40 ± 9.0	6.0 ± 1.3
SC-5	7.0 ± 0.10	4.3 ± 0.50	13 ± 8.6	75 ± 8.9	12 ± 4.3
SC-6	6.9 ± 0.23	3.3 ± 0.44	31 ± 6.2	52 ± 4.7	17 ±2.4
SC-7	7.3 ± 0	4.6 ± 0.35	25 ± 3.3	55 ± 3.1	20 ± 0.26
Alexander Reservoir					
ARC- 1	7.4	2.9	19	56.7	24.3
ARC- 2	7.2	2.2	26.6	49.7	23.7
ARC- 3	7.6	2.3	25.5	58.5	16
ARC- 4	7.2	3.7	38.6	40.7	20.7
ARC- 5	7.4	3.3	67.3	20.1	12.6
ARC- 6	7.4	2.5	36.4	46.4	17.2
ARC- 7	7.6	3.0	13	71.9	15.1
ARC- 9	7.4	1.9	32.6	52.7	14.7
ARC- 8	7.5	2.5	84.9	8.4	6.7
ARS- 1	7.4	9.0	41.9	44.1	14
ARS- 2	7.2	1.7	47.5	40.8	11.7
ARS- 3	7.4	6.3	64.6	26.4	9
ARS- 4	7.2	2.6	46.4	42.8	10.8
ARS- 5	7.2	4.0	36.1	46.5	17.4
ARS- 6	7.0	4.8	7.5	78.1	14.4
ARS- 7	7.2	4.0	8.8	72.5	18.7
ARS- 8	7.1	4.4	12.9	70.4	16.7
ARS- 9	7.1	5.0	37.2	50.9	11.9

[a] = Mean ± standard deviation shown for Soda Creek Sample Stations (n=3)
TOC = Total organic carbon
Sand = 0.074 to 2 mm
Silt = 0.002 to 0.074 mm
Clay = ≤ 0.002 mm

TABLE 5-2

CONCENTRATIONS OF TOTAL METALS IN SODA CREEK SEDIMENT SAMPLES (MG/KG DRY WT.)

Site	Ag		As		Cd		Cu		Mo		Ni		Se		V	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
SCC-3	0.052	0.0076	3.6	0.67	0.77	0.46	7.8	1.3	<3		25	8.7	2.0	0.76	35	7.9
SCC-2	0.075	0.026	6.2	0.40	3.2	0.26	10	1.4	<2		25	1.2	2.7	0.26	66	1.6
SCC-1	0.042	0.024	9.2	1.6	0.72	0.33	12	0.26	1	*	85	12	0.82	1.0	50	5.5
SC-1	0.033	0.012	5.8	0.10	25	1.4	8.9	2.2	<4		54	1.0	21	1.2	46	4.6
SC-2	<0.08		30	12	38	15	11	2.6	3.3	0.58	84	33	39	16	75	10
SC-3	0.12	0.078	18	0	46	2.6	13	2.0	8.3	4.0	108	15	91	7.2	98	4.1
SC-4	0.083	0.015	21	6.4	13	1.0	9.5	1.8	<2		41	3.6	8.9	2.8	61	1.4
SC-5	0.43	0.15	28	9.0	48	15	28	12	3	*	44	4.4	11	4.4	204	108
SC-6	0.55	0.14	49	18	37	2.4	12	1.4	<2		45	4.0	5.1	0.90	72	4.8
SC-7	0.29	0.046	24	3.1	29	3.1	8.8	1.1	<2		39	3.6	4.7	0.58	43	4.6

Notes: N = 3
* - only detected in a single sample.

TABLE 5-3

CONCENTRATIONS OF TOTAL METALS IN ALEXANDER RESERVOIR SEDIMENT SAMPLES (MG/KG DRY WT.)

Location	Ag	As	Cd	Cu	Mo	Ni	Se	V
ARC-1	0.06	2.9	0.4	9.3	<1	11	1.2	26.3
ARC-2	0.05	2.9	0.5	7.8	<0.9	10	0.7	21.8
ARC-3	0.04	2.3	0.5	7.1	<0.9	8	0.6	20.4
ARC-4	0.06	2.7	0.5	7.7	<1	9	0.6	22.6
ARC-5	0.03	2.4	<0.3	4.8	<0.8	6	0.7	14.6
ARC-6	0.05	1.9	<0.3	5.6	<0.8	7	0.5	17.9
ARC-7	0.03	2.4	<0.6	6.7	<2	8	1.3	18.5
ARC-9	0.04	1.9	0.3	5.1	<0.8	6	1.2	14.2
ARC-8	<0.02	1.7	<0.2	2.2	<0.6	3	0.4	7.5
ARS-1	0.06	5.1	8	5	<4	14	2.1	20
ARS-2	0.1	3.6	5	5.9	<0.8	13	1.4	20.3
ARS-3	0.04	5	6	4	<3	12	1.4	15
ARS-4	0.09	5.9	6.2	6.3	<1	15	2.3	23.2
ARS-5	0.08	5.6	8.9	6.4	<2	20	1.9	25.2
ARS-6	0.16	7.2	12.3	10.9	<1	20	3.2	38
ARS-7	0.24	11	21	12.4	<1	30	4	48.6
ARS-8	0.3	24	24.9	13.3	<1	35	6	65.8
ARS-9	0.25	18.2	29.5	10	<2	35	6	57

NOTES: < = Less than detection limit.

TABLE 5-4

METAL CONCENTRATIONS (MG/KG DRY WT.) IN SEDIMENT CORES COLLECTED FROM SODA CREEK AND ALEXANDER RESERVOIR.

Location	Sample Depth	Ag	As	Cd	Cu	Mo	Ni	Se	V	pH	TOC (90)
Soda Creek											
SCC-3	0-to-2"	<0.1	3.1	2	8	<3	13	3	31	6.7	8
SCC-3	2-to-7"	0.09	6.4	<1	8	<3	56	3	52	6.8	4.3
SCC-1	0-to-2"	0.06	8.3	0.9	10.7	<0.7	63	1.6	42.2	7.3	3.7
SCC-1	2-to-8"	0.03	7.7	0.9	12.2	<0.9	95	1.2	47.4	7.3	2.5
SC-2	0-to-4"	0.1	22	63.5	16.8	4	81	63	76.4	6.7	5.8
SC-2	4-to-10"	<0.06	24	5	5.3	<2	105	15	66.7	7.1	7
SC-4	0-to-4"	0.08	24	14.6	10.8	<2	48	8.1	67.5	6.7	2.5
SC-4	4-to-10"	0.06	21	11.9	10.2	<1	34	4.9	49.1	7.1	2.5
SC-5	0-to-5"	0.46	27	43	27.6	2	44	11	165	7	3
SC-5	5-to-11"	0.36	15	18.3	12.9	<2	34	3.3	51.5	6.9	3.4
Alexander Reservoir											
ARC-3	0-to-4"	0.05	2.3	0.4	6.3	<0.8	7	0.5	20	7.7	2.7
ARC-3	4-to-8"	0.05	2.4	0.4	6.4	<0.6	8	0.4	18.6	7.8	2.6
ARC-6	0-to-4"	0.05	2.5	0.5	7.2	<0.8	8	<0.3	19.3	7.4	2.6
ARC-6	4-to-12"	0.14	2.4	2.1	9.7	<0.7	12	1.4	32	7.4	2.2
ARC-6	12-to-16"	0.14	3.4	1.9	10.5	<1	14	1.3	41.4	7.7	2.1
ARS-2	0-to-4"	0.08	4.1	5.1	6.8	<0.7	13	1.6	20.7	7.4	2.3
ARS-2	4-to-10"	0.13	4.9	4.9	8.6	<1	16	1.8	26.4	7.3	3.1
ARS-9	0-to-3"	0.21	19	26.2	8.1	<2	33	4.3	44.4	7.2	4.7
ARS-9	3-to-10"	0.33	28	18.7	8.8	<0.9	36	5.3	39.9	7.1	3.3

NOTES: < = Less than detection limit.

TABLE 5-5

SURFACE WATER CHEMISTRY

Field Location	Field pH	Temp	O_2	Conductivity
Alexander Reservoir		°C	(mg/L)	(μmhos/cm)
ARC-3	7.65	3.8	9.93	601
ARC-6	7.94	2.5	10.04	590
ARC-2	7.94	1.6	11.84	584
ARC-9	7.48	6.1	11.91	943
Soda Creek				
SC-6	7.36	4.8	10.41	929
SC-4	7.51	2.5	10.91	1,329
SC-3	7.48	2.3	10.38	1,386
SC-2	6.96	3.3	9.31	1,414
SCC-1	8.05	4.7	11.2	906
SCC-3	6.85	4.3	13.71	788

Laboratory Location	Alkalinity (mg/L CaCO3)	Cadmium (mg/L)	Calcium (mg/L)	Conductivity (umhos/cm)	Hardness (by Calculation) (mg/L CaCO3)	Magnesium (mg/L)	pH (std units)	Selenium (mg/L)	Sodium (mg/L)	Total Dissolved Solids (mg/L)
Alexander Reservoir										
ARC-3	240	<0.0002	70	670	310	32.2	7.8	0.002	25.2	380
ARC-6	240	<0.0002	70.4	650	310	32.1	8.1	0.003	35.9	370
ARS-2	250	<0.0002	73	770	340	37	7.9	0.002	25.6	350
ARS-9	510	0.0008	98.4	1100	580	82.1	7.4	0.004	26.9	640
Soda Creek										
SC-6	490	0.0009	96	1100	570	81.1	7.1	0.003	26.2	640
SC-4	740	0.0003	119	1500	820	127	7.3	0.032	45.4	910
SC-3	740	0.0005	125	1600	870	135	7.3	0.02	48.1	950
SC-2	740	0.0003	121	1800	850	134	6.6	0.04	48.4	980
SCC-1	510	<0.0002	83.3	1100	550	83.2	7.8	<0.001	24.6	590
SCC-3	420	<0.0002	90.1	900	480	63.2	7	0.001	14.6	480

TABLE 5-6

MEAN AND STANDARD DEVIATION (MG/KG CLAY) FOR EACH OF THE CHEMICAL CONSTITUENTS AND PH IN THE SEDIMENTS AT EACH STATION IN SODA CREEK.

Chemical	Statistic (n=3)	Station									
		SCC-3	SCC-2	SCC-1	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	SC-7
Arsenic	mean	18.3	18.8	35.9	49.1	144	103	299	189	226	95.9
	stdev	8.19	2.65	7.19	3.63	30.6	31.9	160	83.8	75.1	13.1
Cadmium	mean	3.84	9.69	2.91	208	199	266	182	326	171	115
	stdev	2.56	0.0799	1.58	16.0	99.3	91.6	39.5	161	33.5	10.8
Copper	mean	38.1	30.2	47.8	74.4	54.8	79.1	128	186	57.1	34.8
	stdev	11.2	2.42	4.68	12.4	19.9	36.4	13.9	109	10.2	4.66
Nickel	mean	131	76.9	333	458	410	601	576	298	209	154
	stdev	71.4	3.41	49.4	48.7	94.3	90.9	188	98.8	26.7	16.0
Selenium	mean	11.8	8.26	3.46	181	206	527	120	71.9	23.2	18.4
	stdev	2.53	1.57	4.54	22.2	103	181	34.5	33.0	3.02	2.11
Silver	mean	0.211	0.231	0.169	0.285	0.180	0.753	1.15	2.75	2.57	1.14
	stdev	0.0657	0.0920	0.102	0.109	0.0527	0.708	0.322	0.541	0.826	0.192
Vanadium	mean	205	200	195	389	374	565	846	1368	332	169
	stdev	76.1	19.3	2.153	16.7	21.1	198	198	946	50.6	19.9
pH	mean	6.83	6.87	7.27	6.80	6.43	6.93	6.67	7.00	6.87	7.30
	stdev	0.058	0.058	0.3	0.00	0.058	0.153	0.115	0.10	0.231	0.00

TABLE 5-7

MEAN AND STANDARD DEVIATION (MG/KG CLAY) FOR EACH OF THE CHEMICAL CONSTITUENTS AND PH FOR EACH GROUP IN THE SEDIMENT SAMPLES FROM THE RESERVOIR.

Chemical		Reference (n=9)	Group 1 (n=3)	Group 2 (n=3)	Group 3 (n=3)
Arsenic	mean	13.9	37.8	41.1	101
	stdev	4.41	11.6	10.7	44.2
Cadmium	mean	1.62	51.2	58.1	146
	stdev	0.664	9.95	15.3	62.9
Copper	mean	34.3	40.5	51.2	65.6
	stdev	4.25	8.46	16.9	8.06
Nickel	mean	41.7	106	118	190
	stdev	3.94	16.7	12.2	60.9
Selenium	mean	4.69	13.1	16.3	30.8
	stdev	2.07	1.38	5.58	12.8
Silver	mean	0.219	0.539	0.720	1.48
	stdev	0.0421	0.249	0.285	0.364
Vanadium	mean	101	149	187	323
	stdev	11.1	20.4	51.6	97.1
pH	mean	7.41	7.33	7.13	7.13
	stdev	0.145	0.115	0.115	0.0577

Notes:

Reference consists of samples ARC-1, 2, 3, 4, 5, 6, 7, 8, and 9.
Group 1 consists of samples ARS-1, 2, and 3.
Group 2 consists of samples ARS-4, 5, and 6.
Group 3 consists of samples ARS-7, 8, and 9.

TABLE 5-8.

RESULTS OF ANOVAS AND DUNNETT'S MULTIPLE COMPARISON FOR EACH OF THE CHEMICAL CONSTITUENTS AND PH FOR EACH GROUP IN THE SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR.

Chemical	ANOVA p-value	Results of Dunnett's Multiple Comparisons†		
		Group 1	Group 2	Group 3
Arsenic	≤0.0001	**	***	***
Cadmium	≤0.0001	***	***	***
Copper	0.0008	NS	*	***
Nickel	≤0.0001	***	***	***
Selenium	≤0.0001	**	***	***
Silver	≤0.0001	**	***	***
Vanadium	≤0.0001	*	**	***
pH	0.0090	NS	*	*

† *** p-value ≤ 0.001
** 0.001 < p-value ≤ 0.01
* 0.01 < p-value ≤ 0.05
NS Not Significant, p-value > 0.05

Notes:

Reference consists of samples ARC-1, 2, 3, 4, 5, 6, 7, 8, and 9.
Group 1 consists of samples ARS-1, 2, and 3.
Group 2 consists of samples ARS-4, 5, and 6.
Group 3 consists of samples ARS-7, 8, and 9.

TABLE 5-9

MEAN AND STANDARD DEVIATION FOR EACH OF THE BENTHIC ORGANISMS THE SEDIMENTS AT DEPOSITIONAL STATIONS IN SODA CREEK.

	Statistic	Station									
Benthic Organism	(n=3)	SCC-3	SCC-2	SCC-1	SC-1	SC-2	SC-3	SC-4	SC-5	SC-6	SC-7
Tubificidae	mean	26681	35507	92304	24478	18638	18870	41159	25261	2058	11884
	stdev	13042	14648	42587	4500	9743	5037	18453	9932	2000	7082
Tanytarsini	mean	23522	35058	0	10565	1797	145	493	16753	1739	7217
	stdev	14582	33343	0	8177	1515	251	327	13634	1959	2153
Orthocladiinae	mean	1101	449	0	768	12812	174	1058	4290	1029	594
	stdev	1053	201	0	584	10979	157	1373	3391	1377	262
Chironomini	mean	913	101	0	246	58	217	101	5000	2609	73029
	stdev	242	176	0	289	100	376	176	4174	2269	39230
Tanypodinae	mean	275	72	116	0	0	0	478	9522	3319	478
	stdev	338	125	201	0	0	0	441	5994	4958	441
Ostracoda	mean	217	0	101	0	0	0	0	232	87	478
	stdev	376	0	176	0	0	0	0	201	76	200
Lumbriculidae	mean	0	768	101	449	870	1739	391	174	0	0
	stdev	0	887	176	370	870	2539	678	174	0	0
Helobdella stagnalis	mean	0	174	304	174	536	290	0	101	0	667
	stdev	0	157	285	301	522	283	0	176	0	500
Dina sp.	mean	0	188	696	0	652	391	101	58	14	0
	stdev	0	326	920	0	726	442	176	100	25	0
Bezzia sp.	mean	0	0	0	681	0	1130	580	174	14	0
	stdev	0	0	0	615	0	1495	756	174	25	0
Nematoda	mean	0	0	0	116	739	290	290	232	14	0
	stdev	0	0	0	100	513	283	502	402	25	0
Naididae	mean	0	0	0	0	0	0	0	0	0	7246
	stdev	0	0	0	0	0	0	0	0	0	6641
Total Invertebrates	mean	52855	72318	94319	37695	37319	24231	44942	62261	11100	102058
	stdev	19903	45747	41187	13566	20999	2865	16762	29520	12836	54408
Total Taxa	mean	5.67	5.33	4.33	7.67	7.67	7.00	6.00	10.33	8.67	8.67
	stdev	2.08	0.58	2.52	1.15	1.53	1.00	1.73	4.04	0.58	2.52

Shaded area indicates the mean is 5% or greater of the total number of invertebrates

TABLE 5-10

MEAN AND STANDARD DEVIATION FOR EACH OF THE BENTHIC ORGANISMS IN EACH GROUP FOR THE SEDIMENT SAMPLES FROM THE RESERVOIR

Benthic Organism	Statistic	Control (n=9)	Group 1 (n=3)	Group 2 (n=3)	Group 3 (n=3)
Tubificidae	mean	3304	8333	4681	12377
	stdev	1826	8086	479	8317
Chironomus sp.	mean	1082	1160	840	565
	stdev	1049	1037	645	399
Naididae	mean	411	1464	725	898
	stdev	608	1058	411	805
Tanytarsus sp.	mean	82	174	174	855
	stdev	118	87	44	1093
Phaenopsectra sp.	mean	106	43	159	333
	stdev	175	44	165	427
Dicrotendipes sp.	mean	29	29	0	101
	stdev	58	25	0	176
Nais (communis)	mean	43	275	72	319
	stdev	53	266	91	329
Procladius sp.	mean	29	72	14	72
	stdev	38	50	25	66
Podocopa sp.	mean	14	159	0	58
	stdev	22	276	0	100
Total Invertebrates	mean	5182	11853	6709	15636
	stdev	2504	11004	140	11106
Total Taxa	mean	7.89	10.67	7.00	10.33
	stdev	2.47	4.73	1.00	2.31

Shaded area indicates the mean is 5% or greater of the total number of invertebrates

TABLE 5-11

CANONICAL COEFFICIENTS FOR THE SEDIMENT SAMPLES FROM SODA CREEK.

First Set of Coefficients			
Benthic Variable	Canonical Coefficient	Metal	Canonical Coefficient
Tubificidae	1.7973	Silver	-0.9441
Total Invertebrates	-1.1625	Vanadium	0.8245
Tanytarsini	0.4205	Copper	0.5307
Total Taxa	0.3497	Arsenic	-0.4186
Chironomini	-0.1315	Nickel	-0.3476
Orthocladiinae	0.1265	Cadmium	0.1119
Tanypodinae	-0.0291	Selenium	0.0564
Second Set of Coefficients			
Benthic Variable	Canonical Coefficient	Metal	Canonical Coefficient
Tanytarsini	0.6945	Cadmium	1.1772
Total Taxa	0.4189	Nickel	-1.1893
Total Invertebrates	-0.2508	Vanadium	0.8747
Orthocladiinae	0.1680	Silver	-0.3284
Chironomini	-0.0950	Copper	-0.2621
Tanypodinae	0.0822	Selenium	-0.2122
Tubificidae	0.0678	Arsenic	-0.1029

TABLE 5-12.

BENTHIC ORGANISMS IDENTIFIED IN SEDIMENTS FROM SODA CREEK EROSIONAL STATIONS

Benthic Organism	SCC-1D	SCC-2D	SC-1D	SC-2D	SC-3D	SC-4D	SC-5D	SC-6D	SC-7D
Nematoda	0	0	0	215	215	0	11	43	0
Tubificidae	15953	3655	10535	7450	4257	989	2580	1462	3225
Naididae	0	0	0	0	0	0	0	0	1376
Helobdella stagnalis	645	387	720	0	0	86	0	0	0
Dina sp.	215	43	140	0	301	43	11	0	0
Hyalella azteca	1720	0	140	0	86	0	0	0	0
Gammarus lacustris	172	0	0	0	301	430	0	0	0
Baetis sp.	0	9116	0	1580	172	0	0	0	0
Psychoronia sp.	0	215	4085	0	0	537	0	0	0
Optioservus sp.	301	43	0	0	0	699	11	0	43
Orthocladiinae	43	2451	14405	15050	1376	21	129	5848	11266
Tanytarsini	43	1892	8310	1000	0	0	54	387	946
Chironomini	43	0	75	0	0	11	11	129	473
Simulium sp.	0	0	0	0	0	0	0	430	559
Physa sp.	215	0	0	0	602	118	0	0	0
Sphaerium sp.	0	0	215	0	0	11	0	0	86
Total Invertebrates	19436	17845	38840	25585	7353	3095	2807	8471	18275
Total Taxa	12	9	11	8	9	13	7	8	13

TABLE 5-13

MEAN AND STANDARD DEVIATION OF PERCENT MORTALITY AND ORGANISM DRY WEIGHT OF EACH STATION FOR THE SEDIMENT SAMPLES.

Soda Creek

Parameter	Statistic	Lab Control (n=24)	SCC-3 (n=9)	SCC-2 (n=9)	SCC-1 (n=6)
Mortality (%)	mean	17.9	7.78	8.89	18.3
	stdev	13.8	6.67	7.82	16.0
Dry Weight mg/organism	mean	0.921	1.98	1.53	1.97
	stdev	0.308	0.512	0.335	0.606

Parameter	Statistic	SC-1 (n=7)	SC-2 (n=7)	SC-3 (n=5)	SC-4 (n=6)	SC-5 (n=7)	SC-6 (n=14)	SC-7 (n=15)
Mortality (%)	mean	28.6	22.9	38.0	18.3	12.9	19.3	52.7
	stdev	36.3	17.0	36.3	7.53	13.8	28.4	41.1
Dry Weight mg/organism	mean	1.46	1.10	1.26	1.12	1.47	1.61	0.933
	stdev	0.673	0.311	0.760	0.354	0.189	0.602	0.613

Alexander Reservoir

Parameter	Statistic	Lab Control (n=24)	Reference (n=27)	Group 1 (n=9)	Group 2 (n=9)	Group 3 (n=9)
Mortality (%)	mean	17.9	9.67	4.33	6.67	9.00
	stdev	13.8	5.72	2.31	6.51	3.46
Dry Weight mg/organism	mean	0.921	2.36	2.07	1.50	1.27
	stdev	0.308	0.235	0.208	0.300	0.153

TABLE 5-14.

RESULTS OF TUKEY'S MULTIPLE COMPARISON TEST FOR ORGANISM DRY WEIGHT OF THE SEDIMENT SAMPLES FROM ALEXANDER RESERVOIR.

	Results of Tukey's Multiple Comparisons†			
	Reference	Group 1	Group 2	Group 3
Lab Control	***	***	*	NS
Reference		NS	***	***
Group 1			NS	**
Group 2				NS

† *** p-value ≤ 0.001
** 0.001 < p-value ≤ 0.01
* 0.01 < p-value ≤ 0.05
NS Not Significant, p-value > 0.05